OM

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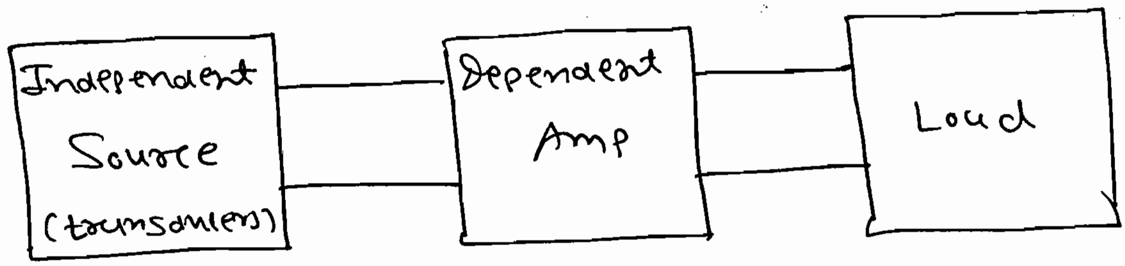
ECE

ACE Academy

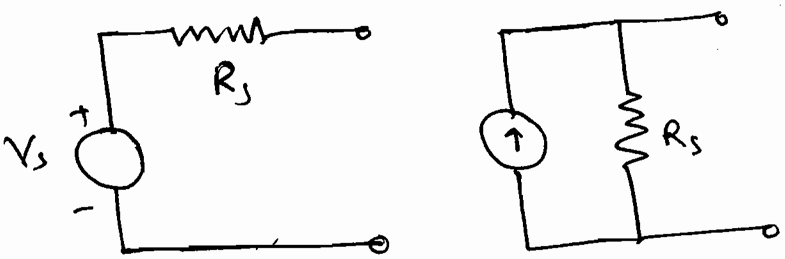
Batch: PM 1(B)

Analog Circuits.

✩ Amplifier Modeling:



→ microphone



* Voltage amp $V_o = kV_{in}$ [VCVS].

Current amp $I_o = kI_{in}$ [CCCS].

Transconduction amp $I_o = kV_{in}$ [VCCS].

TransResistance amp $V_o = kI_{in}$ [CCVS].

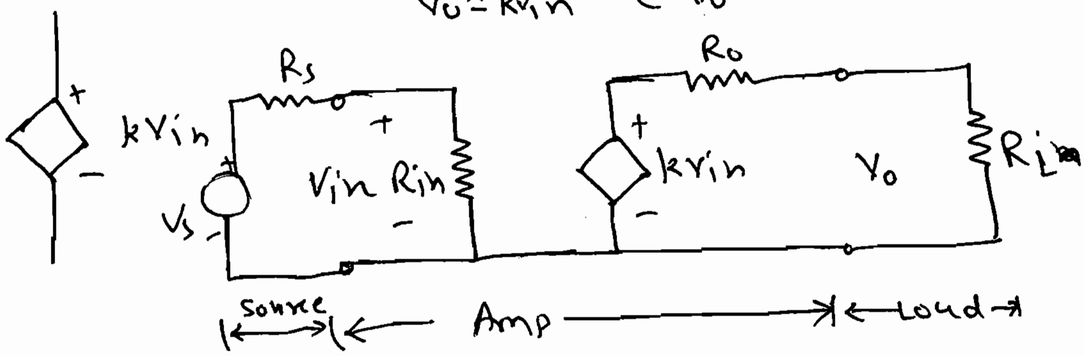
* Four Types of Amplifier:

(1) Voltage amplifier or

Voltage control voltage source.

→ VCVS

$V_o = kv_{in}$ (V_o should be inde. of R_L).



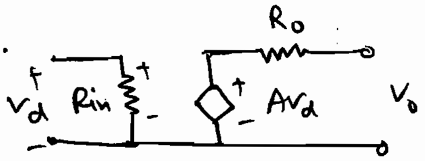
VC → $R_{in} = \infty$, $R_o = 0$. (Ideal).

$v_{in} = V_s$ $V_o = kV_{in}$

NOTE:

→ Amplifier is Unilateral amp. and doesn't violate Reciprocity theorem.

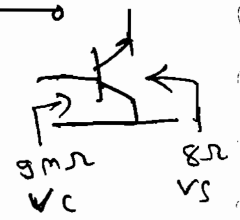
→ Eg: OPAM, CC amplifier



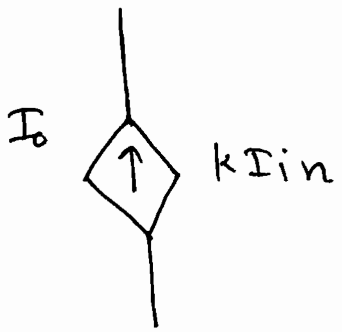
eg-1

(2) Current amplifier or

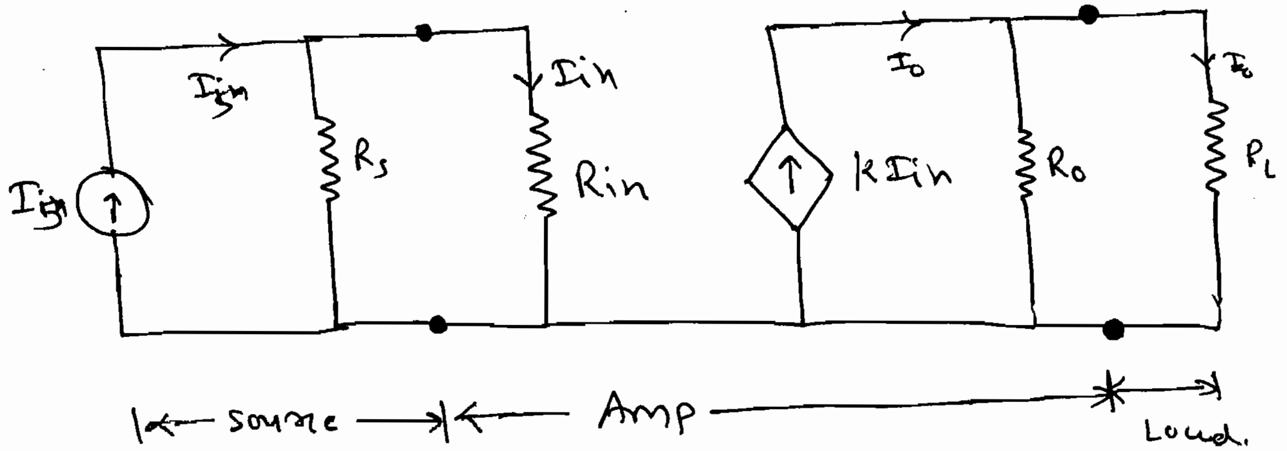
current control current source amplifier.



⇒



(I_o should be independent of Load)

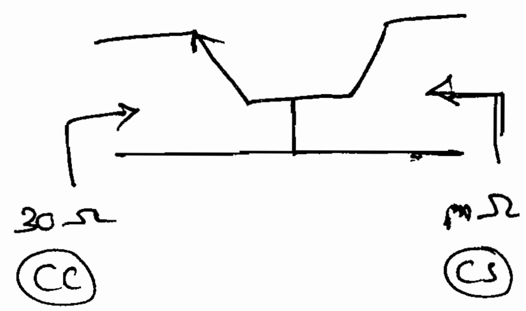


(CC) $R_{in} \approx 0$
⇓
$I_{in} \approx I_s$

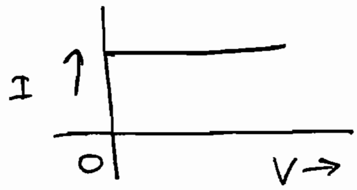
$R_o \approx \infty$
⇓
$I_o = kI_{in}$. (CS)

e.g.:

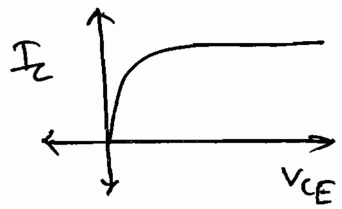
① CB amp



* Characteristics of current source:



e.g. (2) BJT



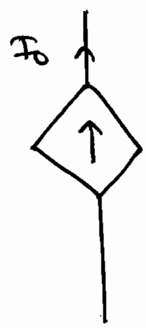
$\Rightarrow R_o = \frac{1}{\text{slop}} = \frac{1}{0} = \infty.$

So, BJT is current source.

(3) Voltage control current source Amp.

(OR) Transconductance Amp.

$\Rightarrow$

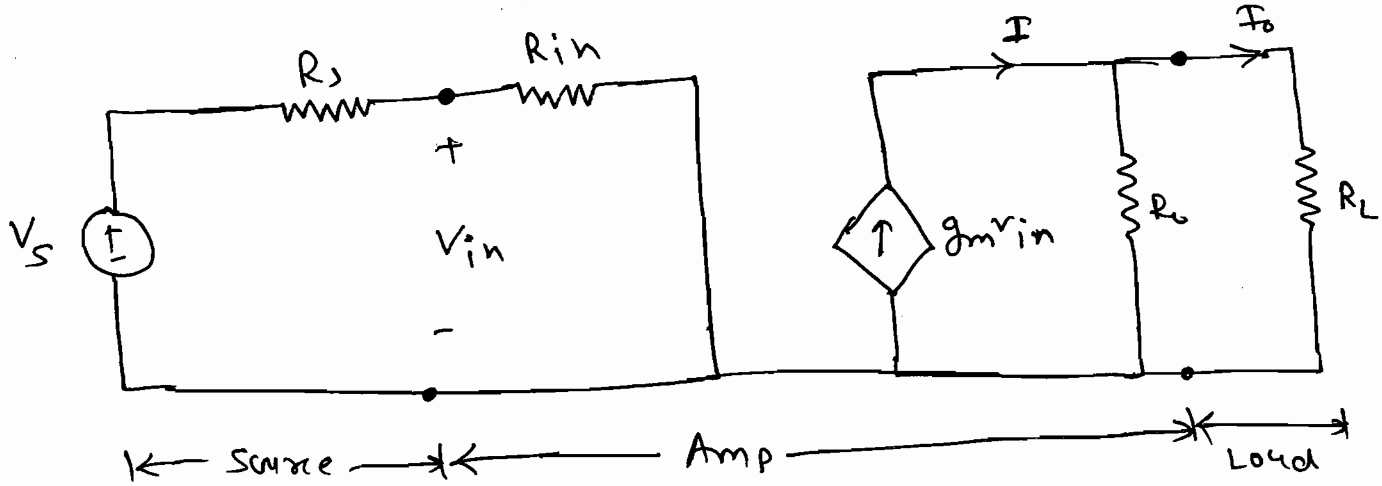


$kV_{in} = gV_{in}$

$\boxed{g_m = \frac{I_o}{V_{in}}}$

g_m → transconductance.

$\therefore I_o = g_m V_{in}.$



$\Rightarrow R_{in} \approx \infty$

$\Downarrow$

$V_{in} \approx V_s$

$\Downarrow$

Voltage control

$R_o \approx \infty.$

$\Downarrow$

$I_o = g_m V_{in}$

$\Downarrow$

current source.

e.g.: ① FET, operational transconductance amp (OTA).

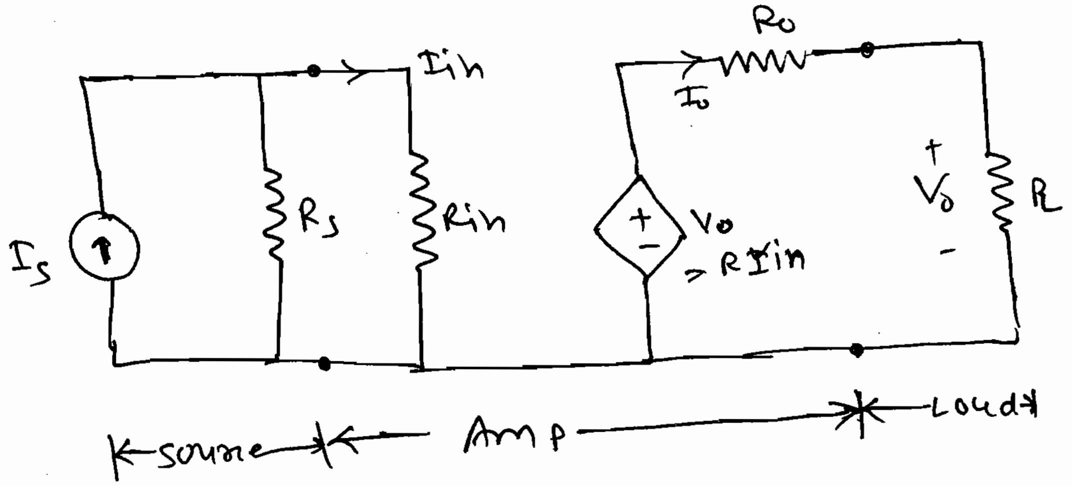
④ Current control Voltage Source:

(OR) Transresistance amp.

$V_o = R_m I_{in}$

$\therefore$ $\boxed{R_m = \frac{V_o}{I_{in}}}$

Trans Resistance



$R_{in} \approx 0$

$\Downarrow$

$\therefore$ $I_{in} \approx I_s$

CC

$R_o \approx 0$

$\Downarrow$

$V_o = R_m I_{in}$

$\Downarrow$

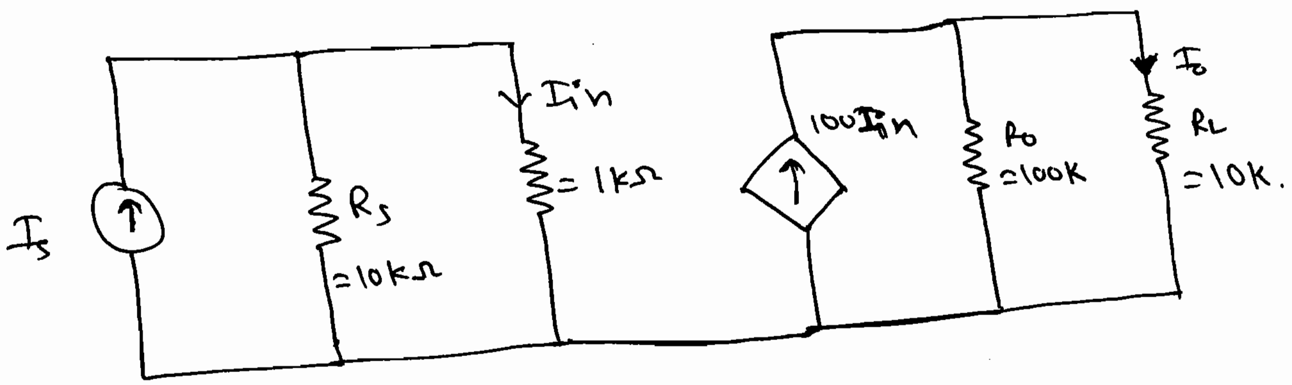
VS

* Summary

Amp	R_{in}	R_o		
1) Voltage	high	Low	$A_v = \frac{V_o}{V_{in}}$	(VSVC).
2) Current	Low	high	$A_I = \frac{I_o}{I_{in}}$	(CSCC).
3) Trans Conductance	high	High	$G_m = \frac{I_o}{V_{in}}$	(CSVC).
4) Trans Resistance	Low	Low	$R_m = \frac{V_o}{I_{in}}$	(VSCC).

Ex-1 Find Voltage gain, current gain and power gain of the current amplifier.

→



$$\rightarrow \quad I_o = \frac{100}{110} \times 100 I_{in}.$$

$$\therefore \quad \frac{I_o}{I_{in}} = A_I = \frac{100 \times 100}{110}.$$

$$\therefore \quad \cancel{A_I = \frac{10^4}{110}}$$

$$\therefore \quad \text{Now,} \quad V_o = I_o \times 10k.$$

$$V_o = \frac{100}{110} \times 100 \times 10K \times I_{in}.$$

$$\therefore \quad V_o = \frac{10^8}{110} \times I_{in}.$$

$$\therefore \quad I_{in} = \frac{10k}{11k} \times I_s.$$

$$\therefore \quad I_s = \frac{1k}{11k} \times I_{in}.$$

$\therefore$

$$\therefore \quad I_o = \frac{100 \times 100}{110} \times \frac{10}{11} I_s.$$

$$\therefore \quad \boxed{\frac{I_o}{I_s} = \frac{10^5}{110 \times 11}} = A_I.$$

$\therefore$ Current gain $A_I = \dfrac{10^5}{110 \times 11}$.

$\therefore$ Voltage gain $(A_v) = \dfrac{V_o}{V_s}$.

$\therefore$

$$V_s = 10k \times \frac{1k}{11k} \times I_{in}.$$

$$\therefore \quad V_s = \frac{10 \times 10^3}{11} \times \frac{110}{10^8} \cdot V_o.$$

$$\therefore \quad \boxed{\frac{V_o}{V_s} = A_v = \frac{10^4}{11 \times 110}}.$$

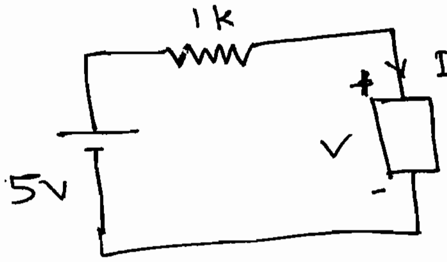
Power gain $(A_p) = A_v \times A_I$

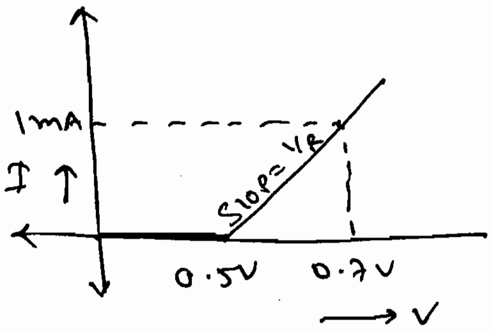
$$\therefore \quad \boxed{A_p = \frac{10^9}{(110)^2 \times (11)^2}}.$$

$\therefore$ Companding means taking log.

$\therefore$ Gain db $= 10 \log A_p$.

Ex-1 Find I of the fig. If Characteristics is given.





∴ $R = \dfrac{0.2}{10^{-3}} = 200\Omega.$

∴ $\text{Slop} = I/V = \dfrac{1}{200}.$

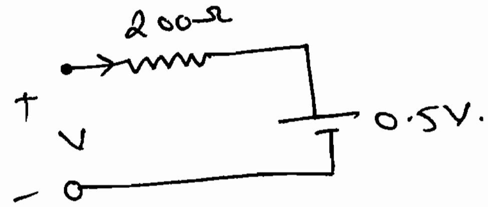
∴ eq. (0.5, 0) to (0.7, 1m).

∴ $\dfrac{y - y_1}{y_2 - y_1} = \dfrac{x - x_1}{x_2 - x_1}.$

∴ $\dfrac{I - 0}{1m} = \dfrac{V - 0.5}{0.2}.$

∴ $200 I + 0.5 = V.$

∴ $\boxed{V = 200 I + 0.5}$

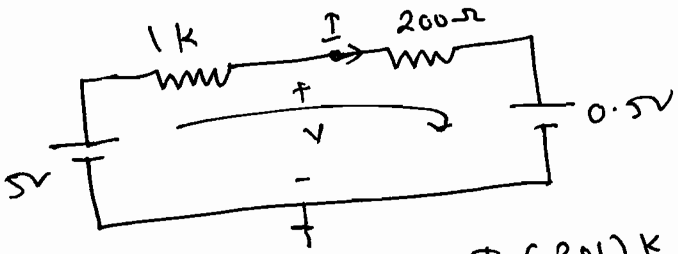


~~Now, V = 1.5 V.~~

~~So, 200 I + 0.5 = 2.5~~

∴ ~~I = 4.5/250.~~

So,



∴ $5 - 0.5 = I(201)K$

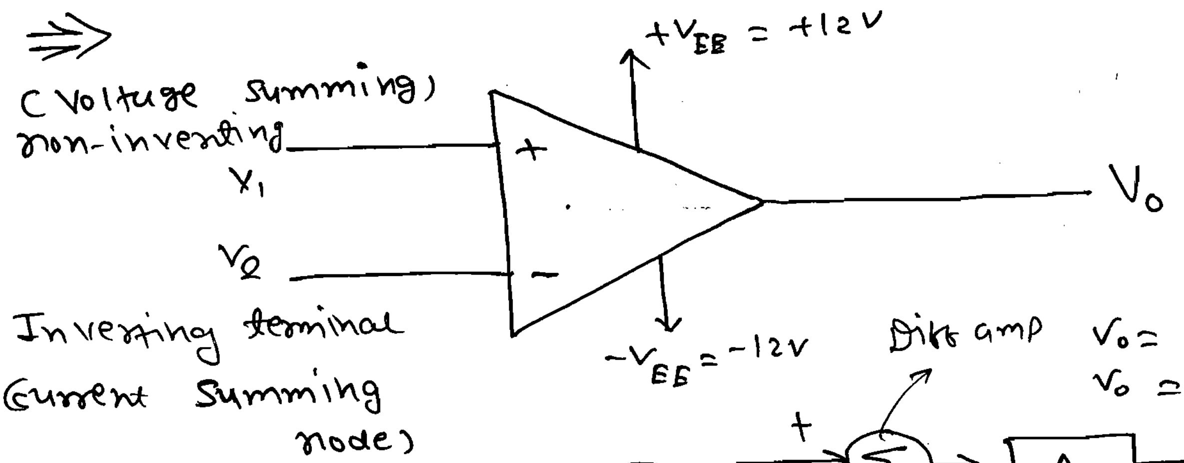
∴ $\boxed{I = 3.75\ mA}$

∴ $V = 200 \times 3.75 \times 10^{-3} + 0.5$

∴ $V = 7.5 + 0.5 = 0.8\ V. \Rightarrow \boxed{V = \cancel{0.8V}}$ 1.25V

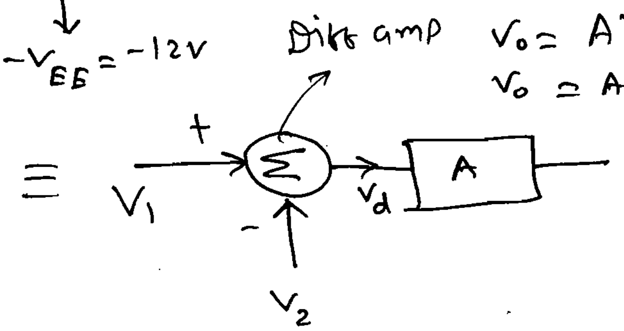
☆ Operational amplifier: (OP-Amp)

⇒



$V_o = AV_d$
$V_o = A(V_1 - V_2)$

≡

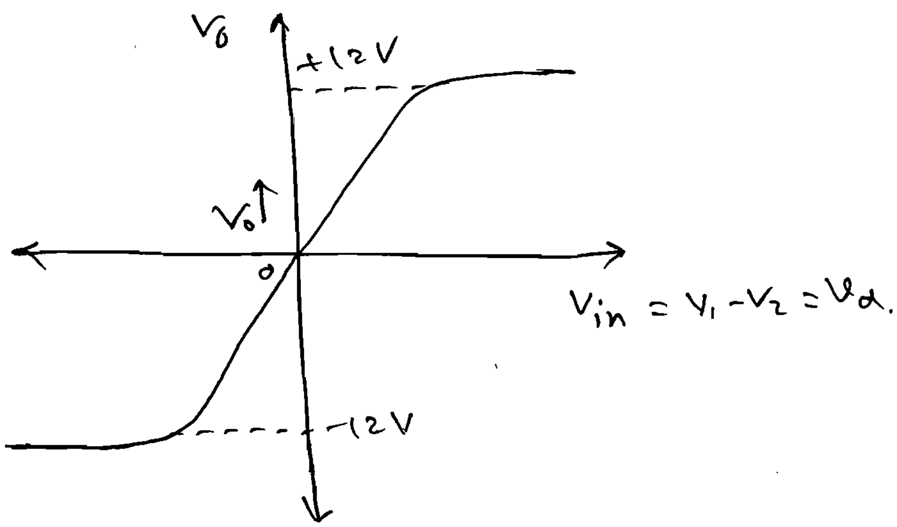


$$\therefore \quad V_o = A_{OL}(V_1 - V_2).$$

A_{OL} = open loop gain → 10^6 [μA741 Fairchild].

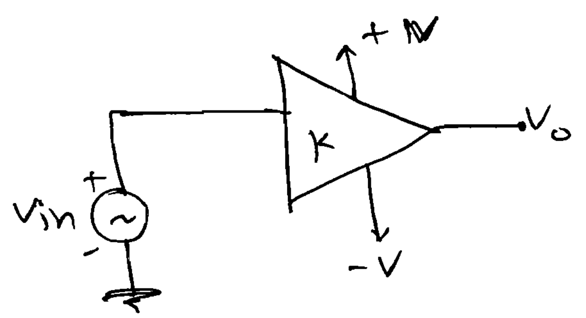
→ OP-Amp is a high gain differential Amplifier.

* Transfer characteristics:



NOTE: If an amplifier works with two supplies +V and −V with a gain K in order to avoid clipping the input signal swing

Should $-\frac{V}{K}$ to $+\frac{V}{K}$.



$-V \le V_o \le +V$.

$-\frac{V}{K} \le V_{in} \le +V/K$.

* Three Basic Modes of Operation of an Op-Amp:

(1) Negative feedback:

* **Linear**
  - VCVS, CCCS, VCCS, CCVS } Amp
  - Adder
  - subtracter
  - Instrumentation Amp
* **Nonlinear**
  - Rectifier
  - peak Detector
  - Clipper
  - clampper
  - Log amp
  - exp amp.

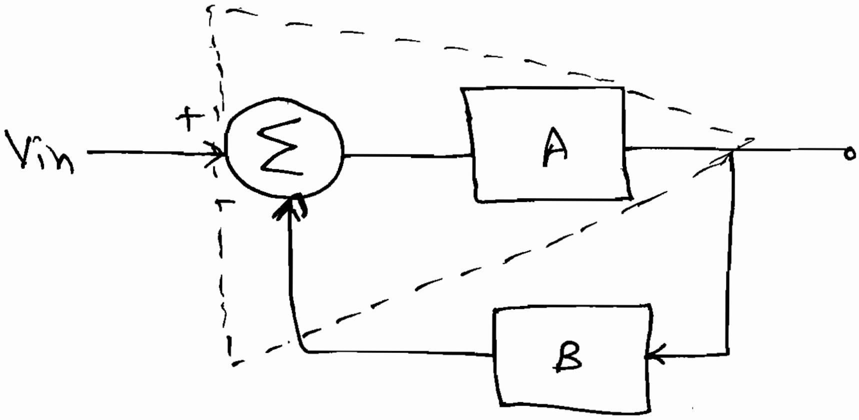
* **Open loop**
  - Comparator (Detector)
* ~~[illegible]~~ **positive feedback**
  - schmit trigger
  - → multivibrators.

MImp II

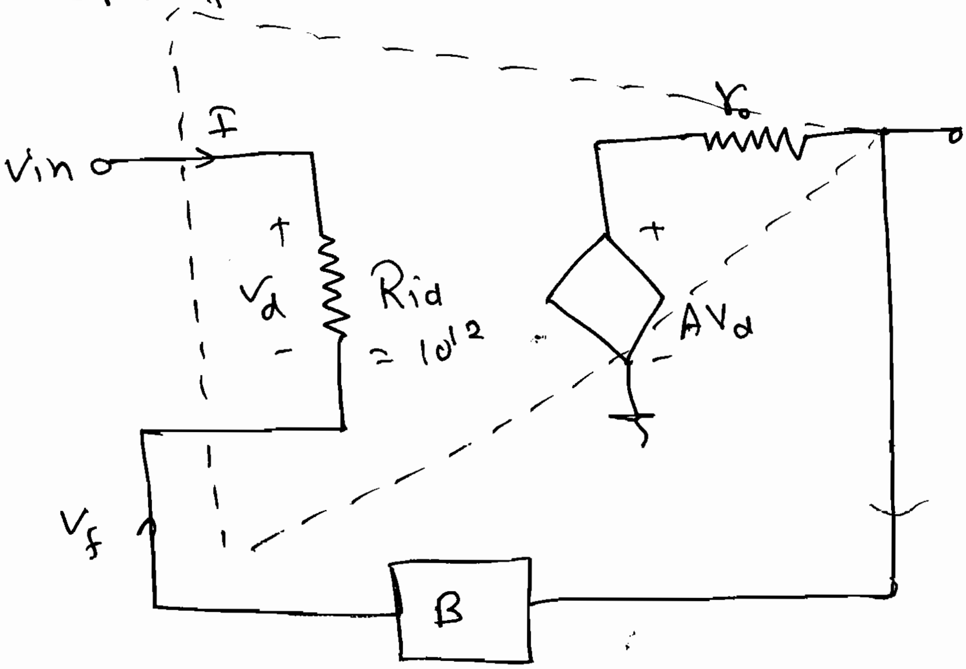
→ In order to solve circuits involving -ve feedback two realistic assumstions are made.

① $\boxed{V_{noniverting} = V_{inverting}}$.

② Op-amp draws no current.

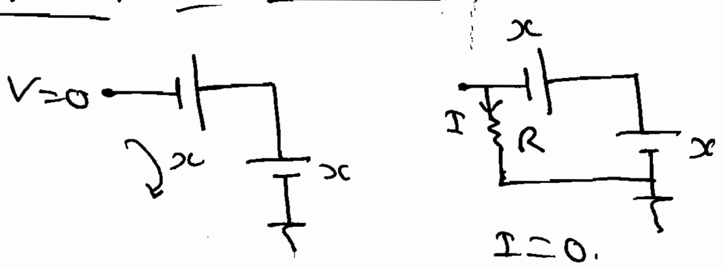


→ OP-Amp is VCVS.



$V_d = \frac{V_o}{A} = \frac{10}{10^6} = 10^{-5}$

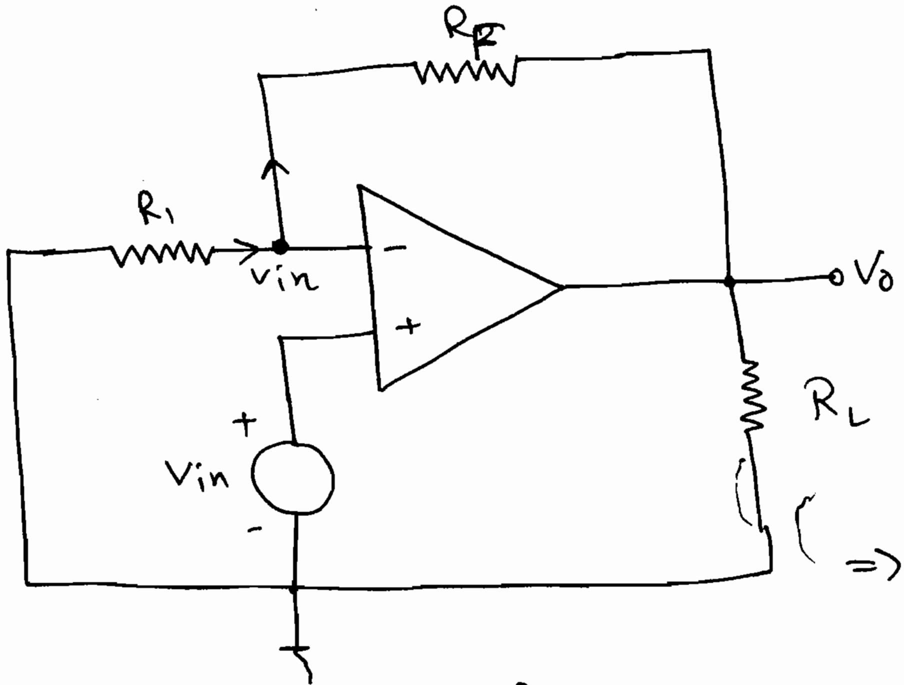
* OP-Amp is nullator.



so, V=0 & I=0.

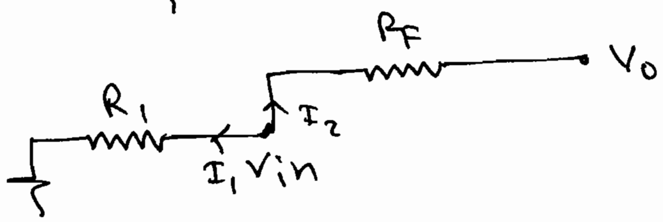
(1) Voltage Amplifier (OR) Non-Inverting Amplifier (OR) Voltage Control Voltage Source Amplifier).

*



⇒ VCVS

⇒



KCL $\quad I_1 = I_2$.

$$\therefore \quad \frac{Vin - 0}{R_1} + \frac{Vin - Vo}{R_F} = 0$$

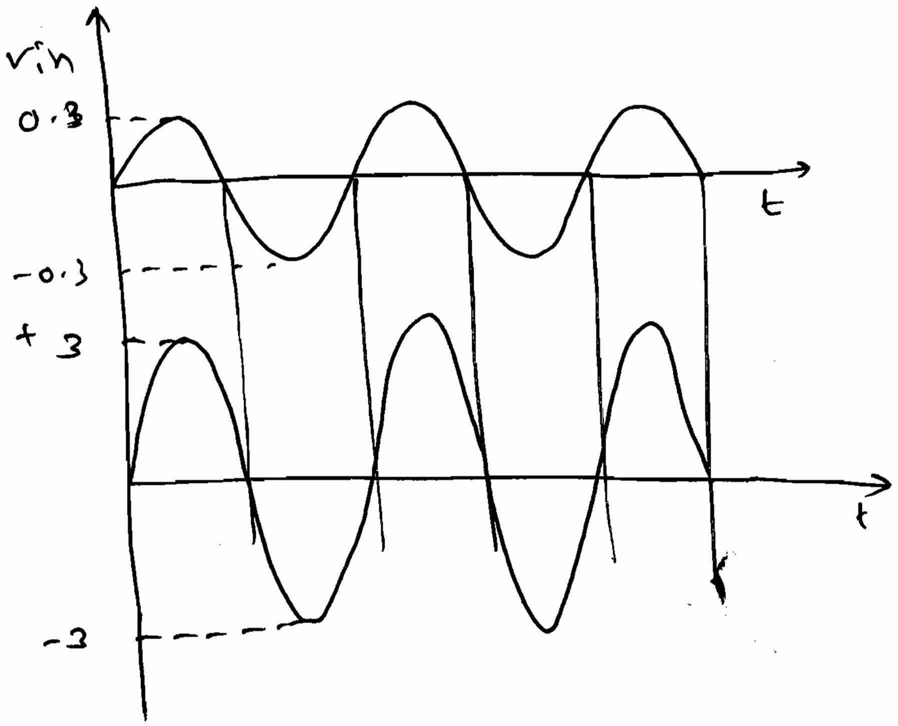
$$\therefore \quad V_o = \left(1 + \frac{R_F}{R_1}\right) Vin$$

$$\therefore \quad \boxed{V_o = K\,Vin.}$$

e.g. $\quad Vin = 0.3 \sin t, \quad R_F = 9K, \quad R = 1K.$

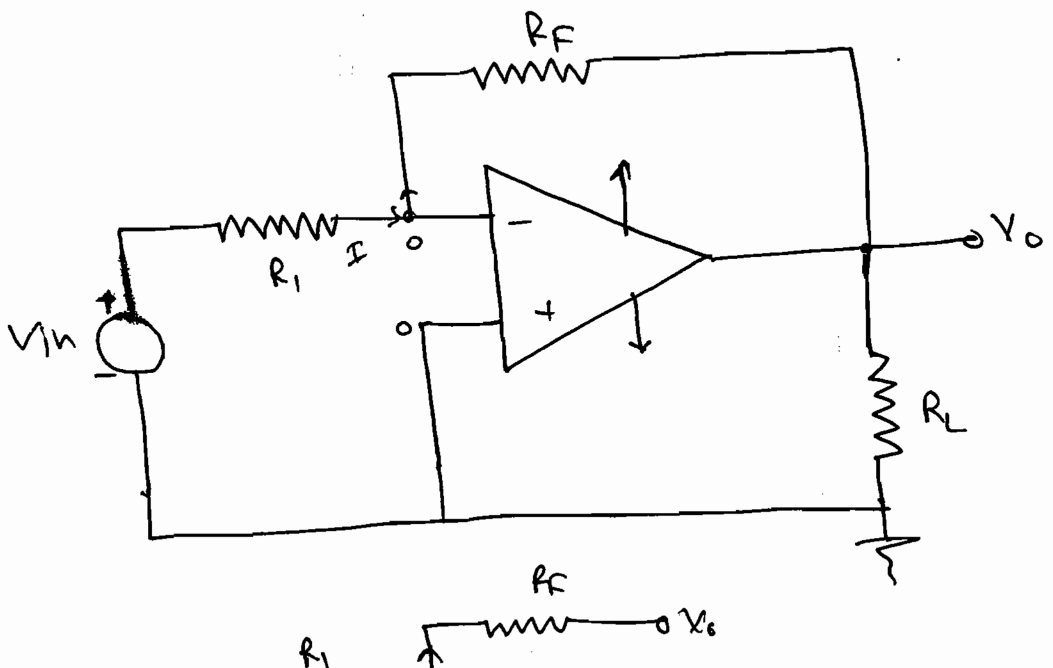
$$\therefore \quad V_o = \left(1 + \frac{9}{1}\right) Vin$$

$$\therefore \quad V_o = 10\,Vin = 3 \sin t.$$



(2) Inverting Amplifier (or) Current Control Voltage Source (or) Trans Resistance Amplifier.

⇒)



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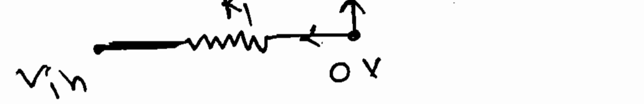


KCL $\frac{0 - V_{in}}{R_1} + \frac{0 - V_o}{R_F} = 0$

$$\therefore \boxed{V_o = \left(-\frac{R_F}{R_1}\right) V_{in}.}$$

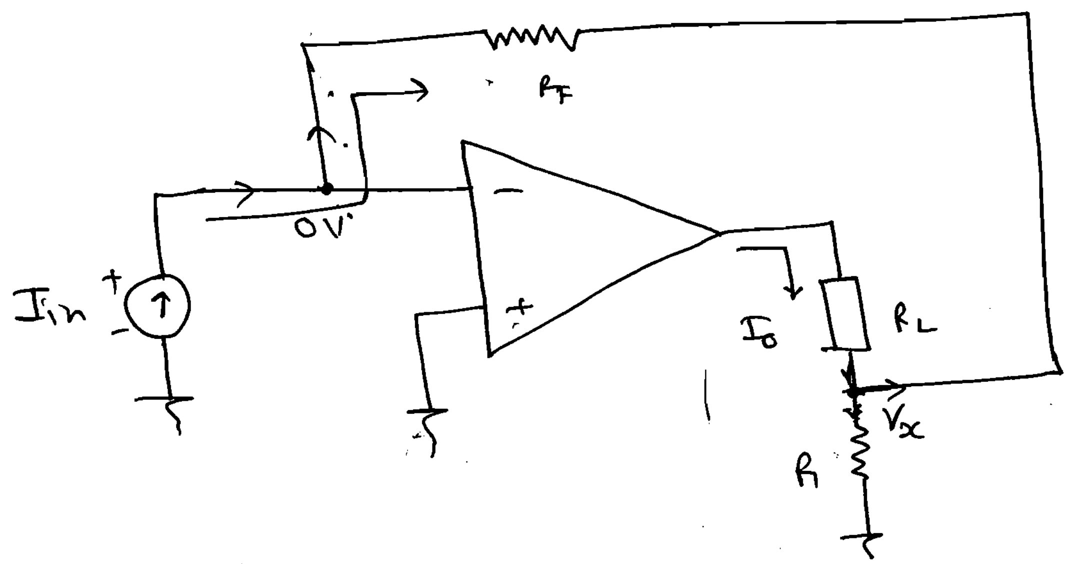
→ $V_o = (-R_F)\left(\frac{V_{in}}{R_1}\right)$ → current control.

$\therefore V_o = -R_F I_{in}$.

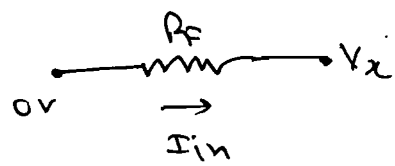
$\therefore$ Trans Resistance $R_m = \frac{V_o}{V_{in}}$.

$\therefore \boxed{R_m = -R_F}$

(3) Current Amplifier (OR) Current Control Current Source:



KCL: $I_o = \frac{V_x}{R_1} + \frac{V_x - 0}{R_F}$.



$\therefore I_o = V_x\left[\frac{1}{R_1} + \frac{1}{R_F}\right]$ —(1)

$\therefore I_{in} = \frac{0 - V_x}{R_F}$.

$\therefore V_x = (-R_F)\, I_{in}$. —(2)

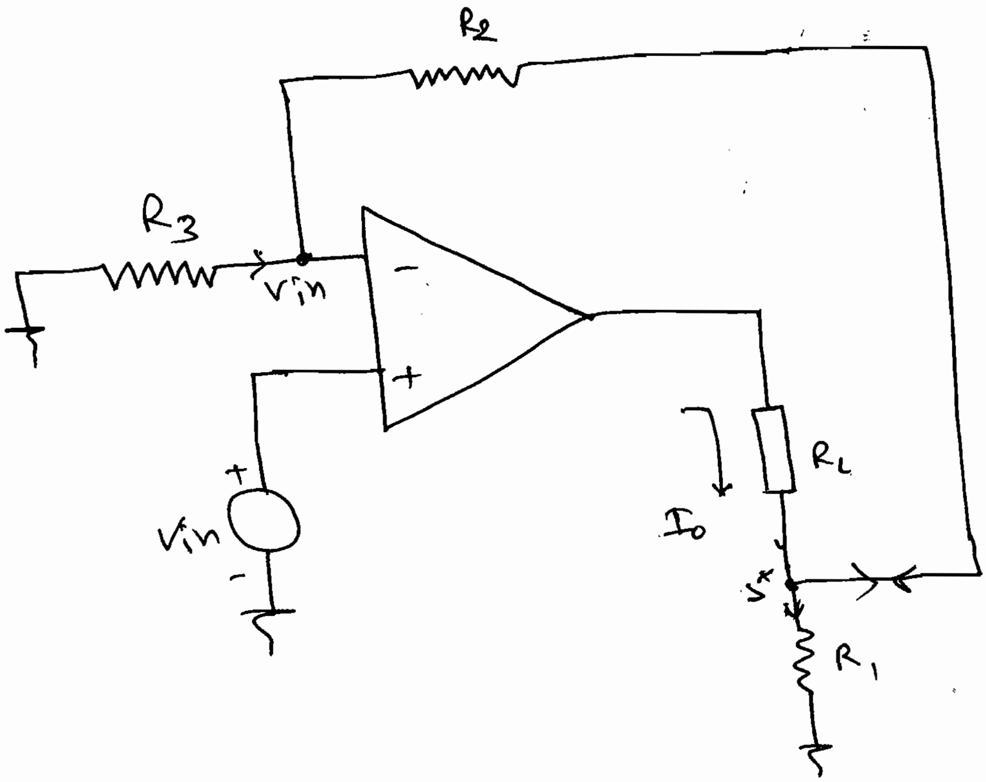
Sub (2) in (1)

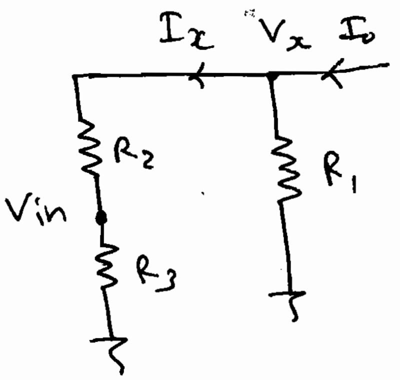
$I_o = -R_F I_{in}\left[\frac{1}{R_1} + \frac{1}{R_F}\right]$.

$\therefore I_o = -\left[1 + \frac{R_F}{R_1}\right] I_{in} \Rightarrow \boxed{I_o = k\, I_{in}}$

(4) Trans conductance Amplifier (OR) Voltage Control ~~Volt~~ Current Source.

→





$$\therefore \quad I_x = \frac{R_1}{R_1 + R_2 + R_3} I_o .$$

$$\therefore \quad V_{in} = I_x \cdot R_3 .$$

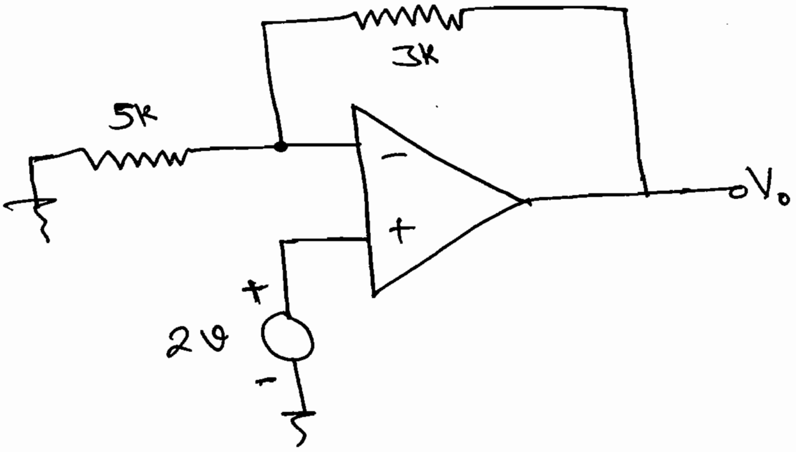
$$\therefore \quad V_{in} = \frac{I_o R_1 . R_3}{R_1 + R_2 + R_3}$$

∴ transconductance

$$\boxed{g_m = \frac{R_1 + R_2 + R_3}{R_1 R_3}}$$

Ex-1 Find the o/p voltage if op-Amp is consider ideal.

①

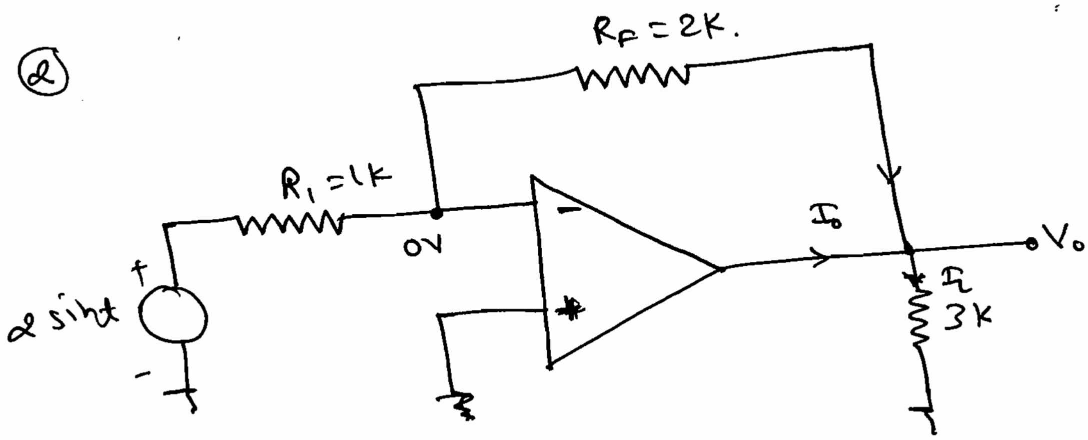


$\therefore V_o = \left(1 + \frac{R_F}{R_1}\right) V_{in}.$

$\therefore V_o = \left(1 + \frac{3}{5}\right) 2V.$

$\therefore \boxed{V_o = \frac{16}{5}\ V}$

②



$\therefore V_o = -\frac{R_F}{R_1} \cdot V_{in}.$

$\therefore V_o = -4\sin t.$

$I_o + I_F = I_L.$

$I_o = I_L - I_F.$

$\therefore = \frac{V_o}{3} - \frac{[0 - V_o]}{2k}$

$= \frac{\cancel{-4\sin t} + \cancel{4\sin t}}{3}$

$\therefore \boxed{\cancel{I_o} = \cancel{\frac{8\sin t}{3}}\ A.}$

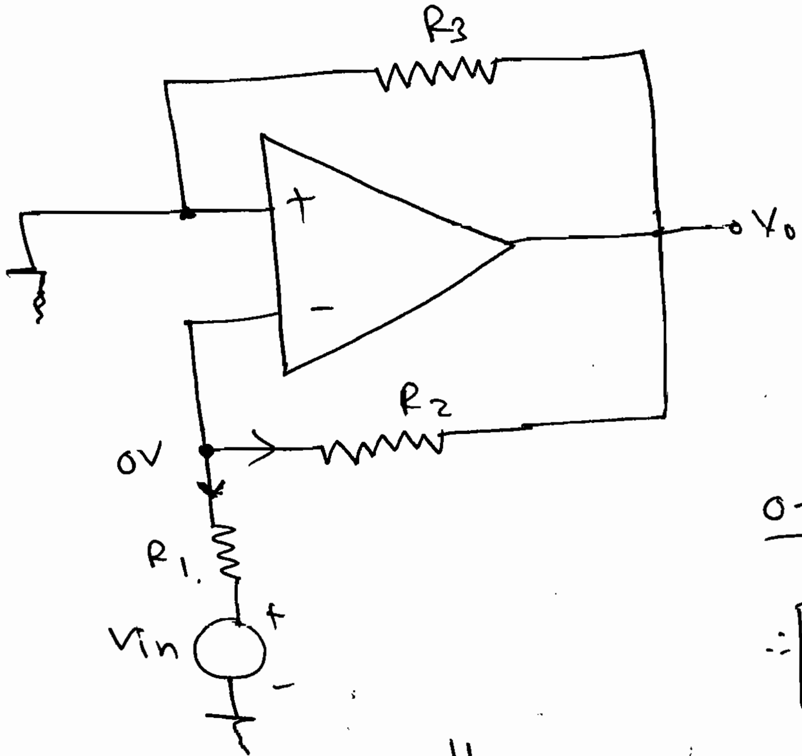
$$I_o = \frac{V_o}{3K} + \frac{V_o}{2K}$$

$$= \frac{5V_o}{6K}$$

$$I_o = \frac{5(-\overset{2}{\cancel{4}}\sin t)}{\cancel{6}_3 K}$$

$$\therefore \boxed{I_o = -\frac{10}{3}\sin t \text{ mA}}$$

Ex- 3

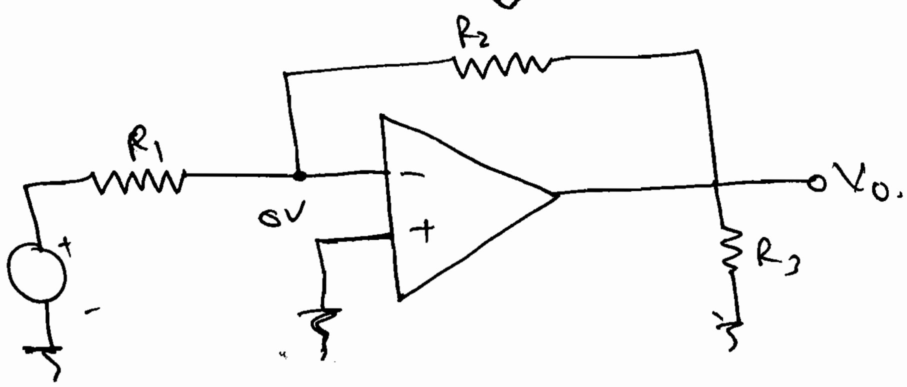


KCL

$$\frac{0 - V_{in}}{R_1} + \frac{0 - V_o}{R_2} = 0$$

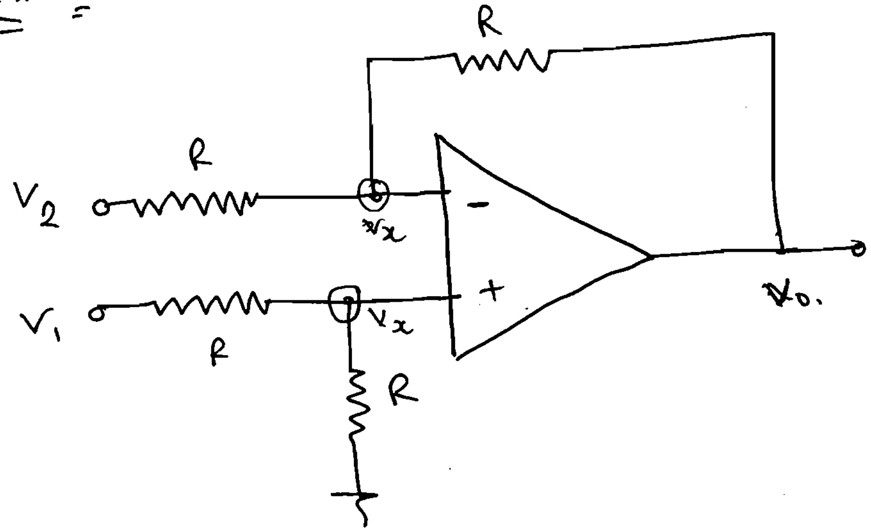
$$\therefore \boxed{V_o = -\left(\frac{R_2}{R_1}\right) V_{in}.}$$

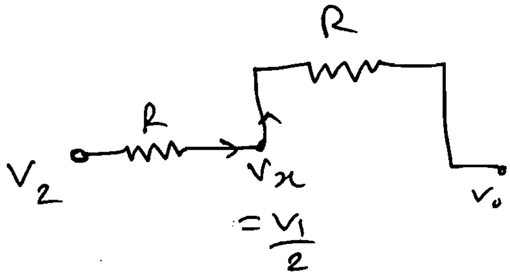
$\Downarrow$



$$\therefore \quad V_o = -\left(\frac{R_2}{R_1}\right) V_{in}.$$

Ex 4





→ By supperposision theorem

① Let $V_2 = 0$ & V_1 is given.

$$\therefore V_x = \frac{R}{R+R} \cdot V_1$$

$$\therefore V_x = V_1/2.$$

$$\therefore V_{01} = \left(1 + \frac{R}{R}\right)\frac{V_1}{2}.$$

$$V_{01} = V_1$$

② Let $V_2 = V$ and $V_1 = 0$.

$$\therefore V_{02} = \left(-\frac{R}{R}\right) V_2.$$

$$\therefore V_{02} = -V_2.$$

$$\therefore V_0 = V_{01} + V_{02}.$$

$$\therefore \boxed{V_0 = V_1 - V_2 . \ V}$$

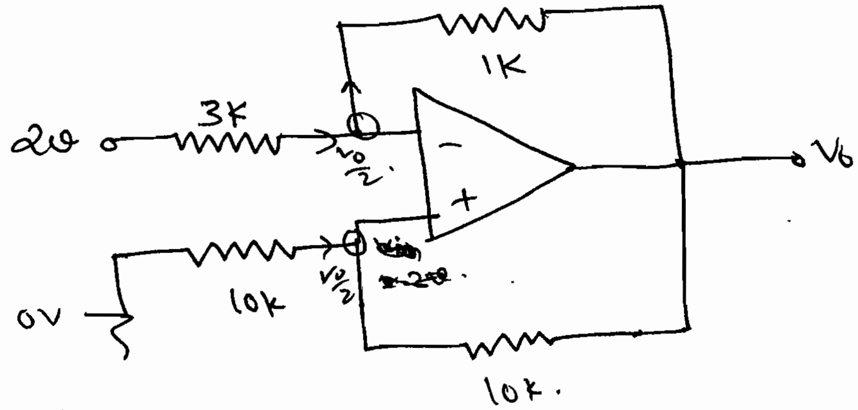
$$\therefore \frac{V_2 - \frac{V_1}{2}}{R} = \frac{\frac{V_1}{2} - V_0}{R}$$

$$\therefore V_2 - V_1 = -V_0$$

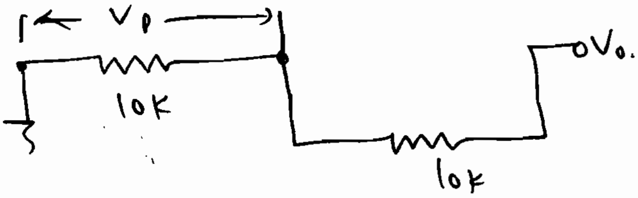
$$\therefore \boxed{V_0 = V_1 - V_2}$$

Subtractor.

Ex-5



→



$\therefore \quad V_P = \frac{V_0}{2}.$

$\therefore \quad \frac{2 - \frac{V_0}{2}}{3} = \frac{\frac{V_0}{2} - V_0}{1}.$

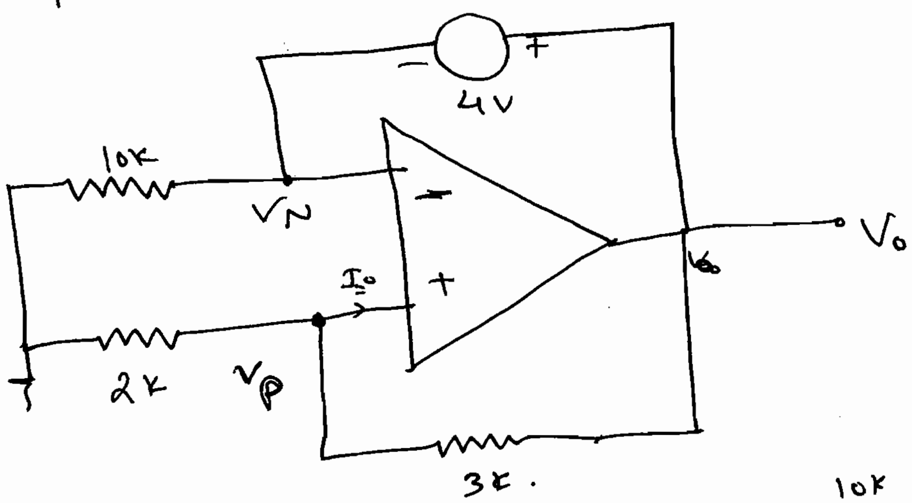
$\therefore \quad \frac{4 - V_0}{\cancel{6}\,3} = -\frac{V_0}{\cancel{2}}.$

$\therefore \quad 4 - V_0 = -3V_0.$

$2V_0 = -4$

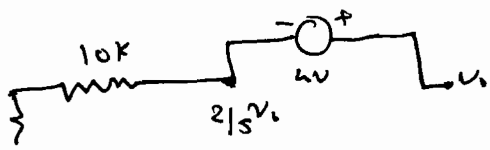
$\boxed{V_0 = -2\,v}$

Ex-6 Find V_P, V_N & V_0.



$\therefore \quad V_P = \frac{2}{5} \times V_0.$

$\therefore \quad \boxed{V_N = V_P = \frac{2}{5} \times V_0}$

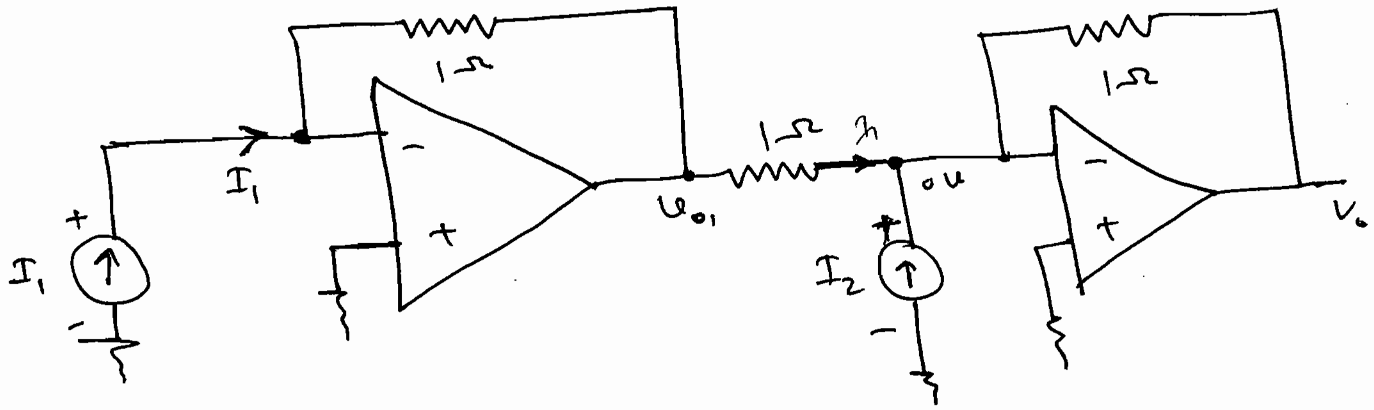


$\therefore \quad V_0 - 2/5\,V_0 = 4\,V.$

$\frac{3}{5} V_0 = 4$

$\therefore \quad \boxed{V_0 = 20/3\,V}.$

Ex-6 Find V_o in terms I_1 & I_2.



$\therefore$ $v_{o1} = -1(I_1)$

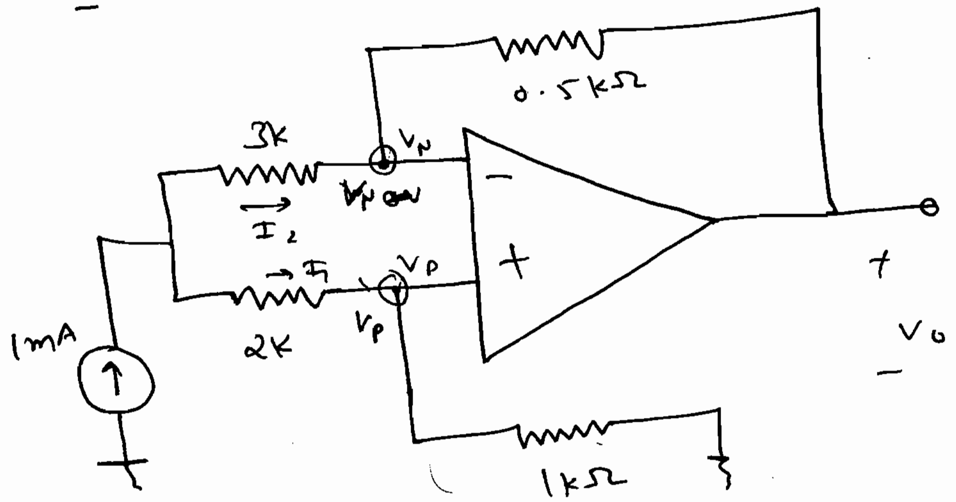
$$\boxed{v_{o1} = -I_1}$$

$$\therefore \quad \frac{v_{o1} - 0}{1} + I_2 = \frac{0 - v_o}{1}$$

$$\therefore \quad -I_1 + I_2 = -v_o$$

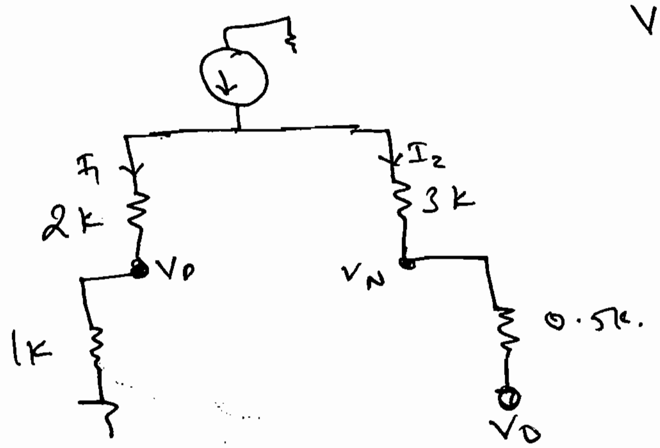
$$\therefore \quad \boxed{v_o = I_1 - I_2.}$$

Ex-8



$V_P = V_N$.

$\therefore$



$$I_1 = \frac{1m(3k)}{2k+3k} = 0.6mA$$

$\therefore$ $I_2 = I - I_1$

$$\boxed{I_2 = 0.4mA}$$

$\therefore$ $V_p = I_1 \times 1k$

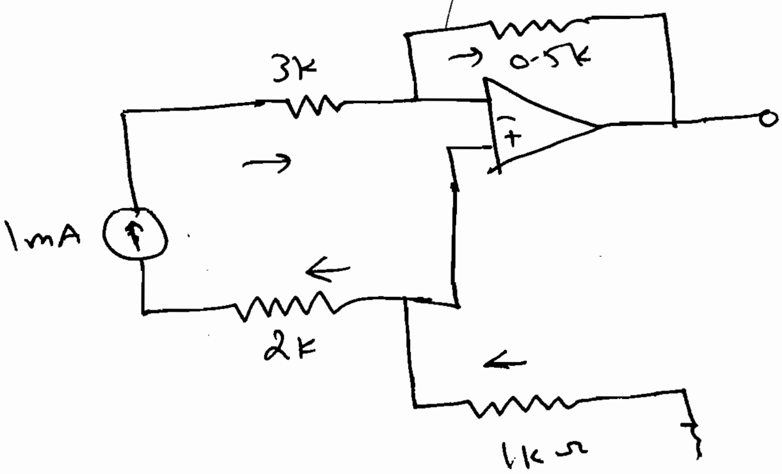
$$\boxed{V_p = 0.6V.}$$

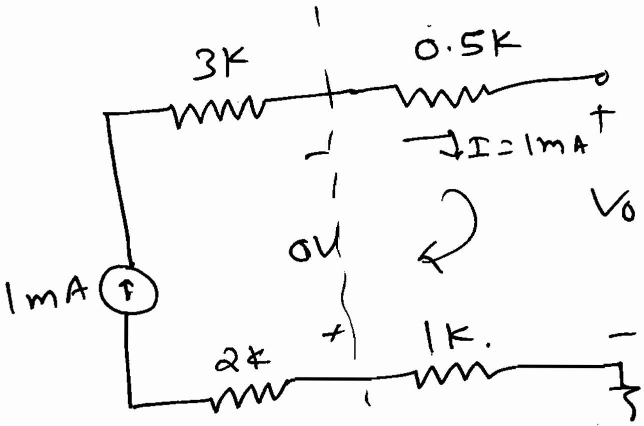
$\therefore$ $I_2 = \frac{V_N - V_0}{0.5k}$

$\therefore$ $0.4m = \frac{0.6 - V_0}{0.5k}.$

$\therefore$ $V_0 = -0.2 + 0.6$

$$\boxed{V_0 = +0.4 V.}$$

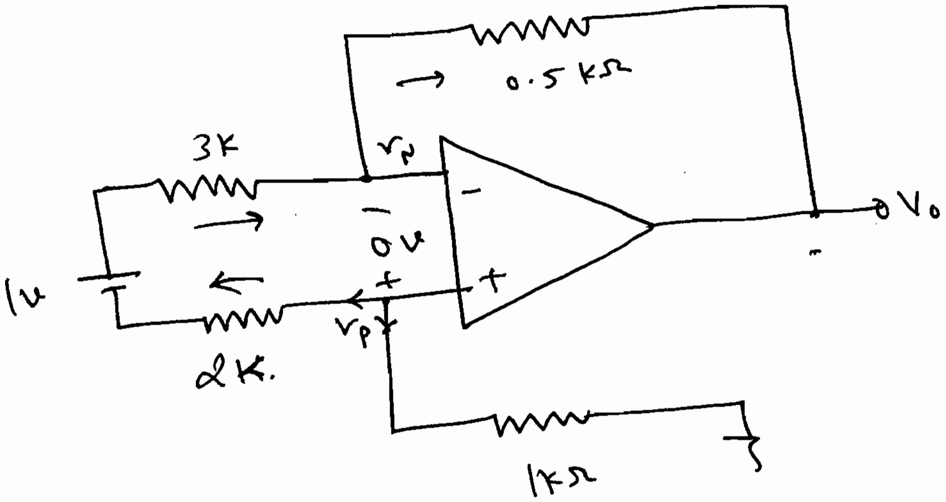




$$0 + I(0.5k) + V_0 + I(1k) = 0$$

$\therefore$ $V_0 = -I(1.5k).$

$$\boxed{V_0 = -1.5V}$$



$\cancel{Y - (3I) - 0.5 - 1 - 2I}$

∴ $-1 + I(3k) - 0 + I(2k) = 0.$

∴ $\boxed{I = 0.2 \text{ mA}}$

∴ $V_p = (-1k)(0.2).,$

∴ $\boxed{V_p = -0.2\,V.}$

∴ $\boxed{V_N = -0.2\,V.}$

∴ $I = \dfrac{V_N - V_o}{0.5k}.$

∴ $0.2m = \dfrac{-0.2 - V_o}{0.5}$

∴ $-0.1 + 0.2 = V_o$

∴ $\boxed{\cancel{V_o = -0.8V}}$

∴ $\boxed{V_o = -0.3\,V.}$

$V_p =$

I G

$I + \dfrac{V_p}{1k} = 0$

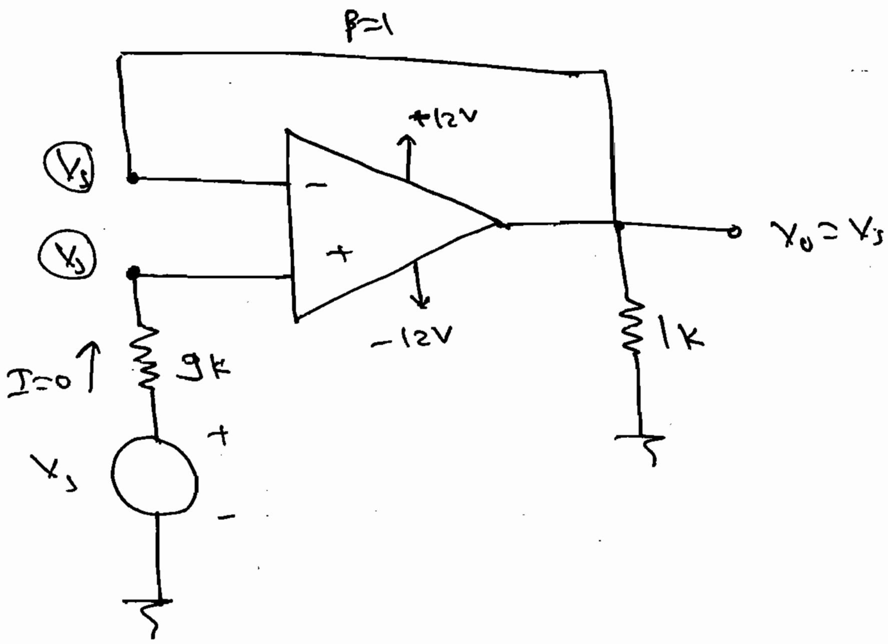
$v_p = (-I)(1k).$

$V_p = (0.2m)(-1k).$

$\boxed{V_p = -0.2V}$

* Buffer (or) Voltage follower (or) Unity gain amplifier.

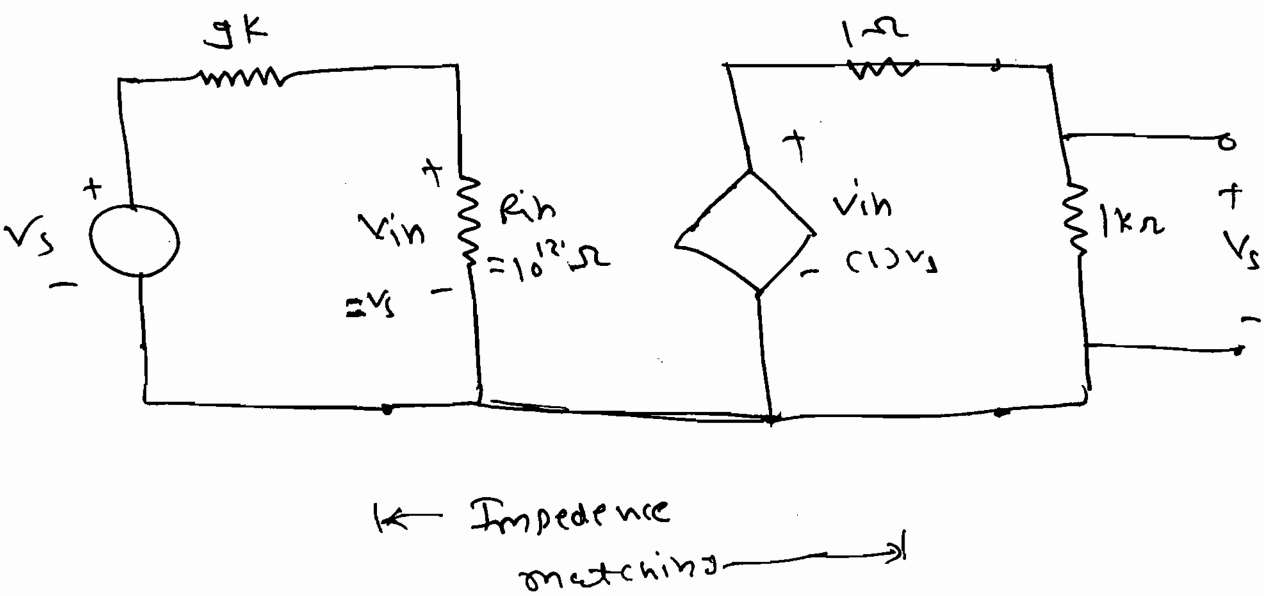
→ Impedence matching device is device which connect high impedence source to low impedence Load.



$$\rightarrow \quad A_f = \frac{A}{1+A\beta} = \frac{10^6}{1+10^6(1)} \simeq 1.$$

$\therefore \boxed{A_f = 1.}$

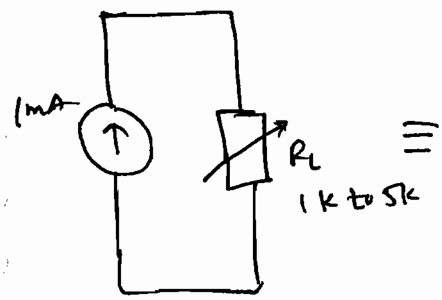
→



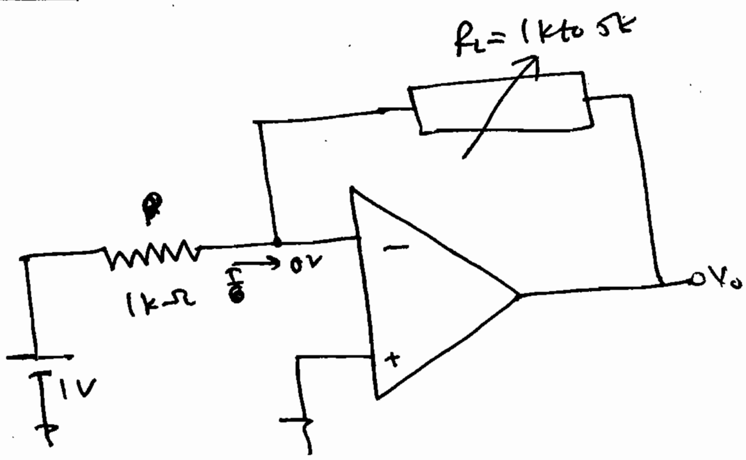
* Voltage Buffer | Current Buffer

Voltage Buffer	Current Buffer
High R_{in}	Low R_{in}
Low R_o	High R_o
$A_V \simeq 1$	$A_I \simeq 1$
High A_I	High A_V
$A_p = A_V A_I$	$A_p = A_V A_I$
$A_p = A_I$	$A_p = A_V$.
e.g. Common Collector.	e.g: Common Base.

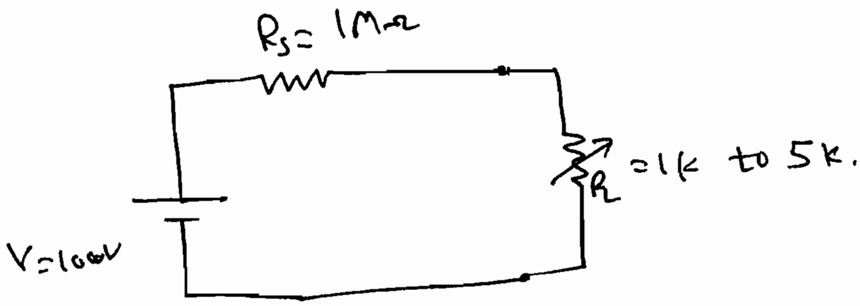
* Building Current Sources:



$\equiv$



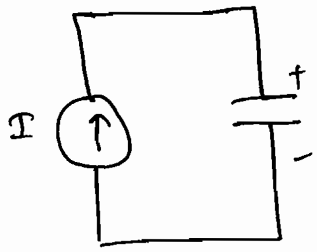
$I = 1mA$.



$R_s >> R_L$

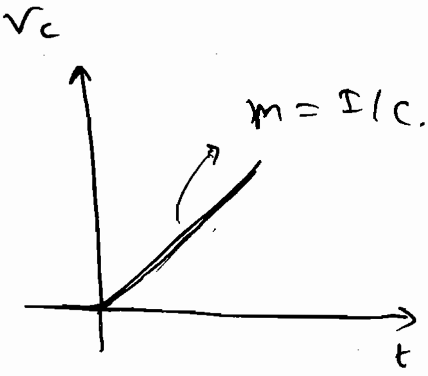
* Miller Integrator:

*



$$V_c = \frac{1}{C}\int I\,dt$$

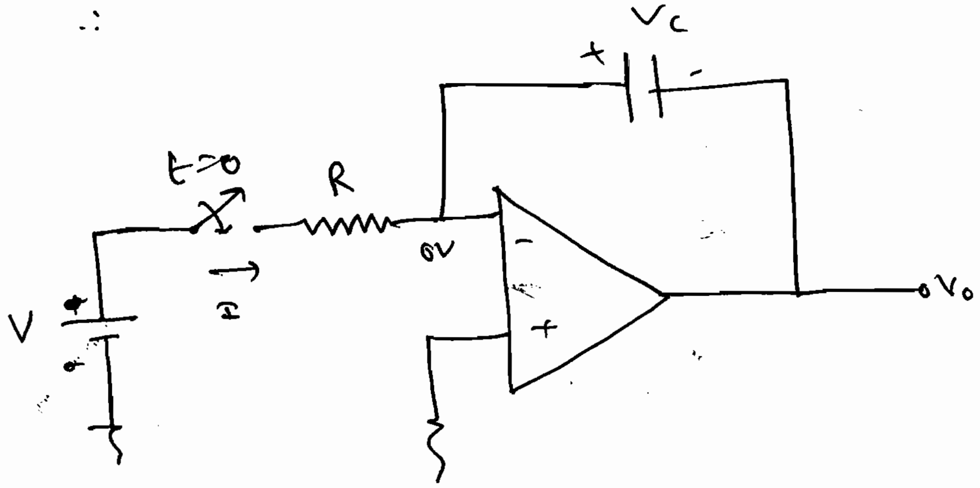
$$V_c = \left(\frac{I}{C}\right)\int dt$$



$\therefore$ $V_c = \left(\frac{I}{C}\right) t$ $\Rightarrow$ $y = V_c$

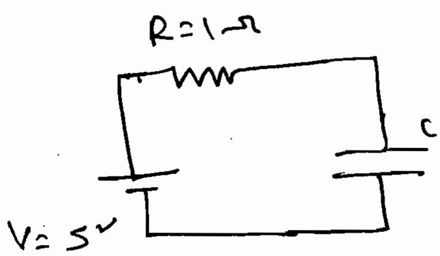
$\therefore$ $y = mx + C.$ $\quad x = t$

$\therefore$

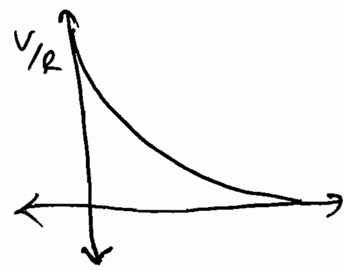


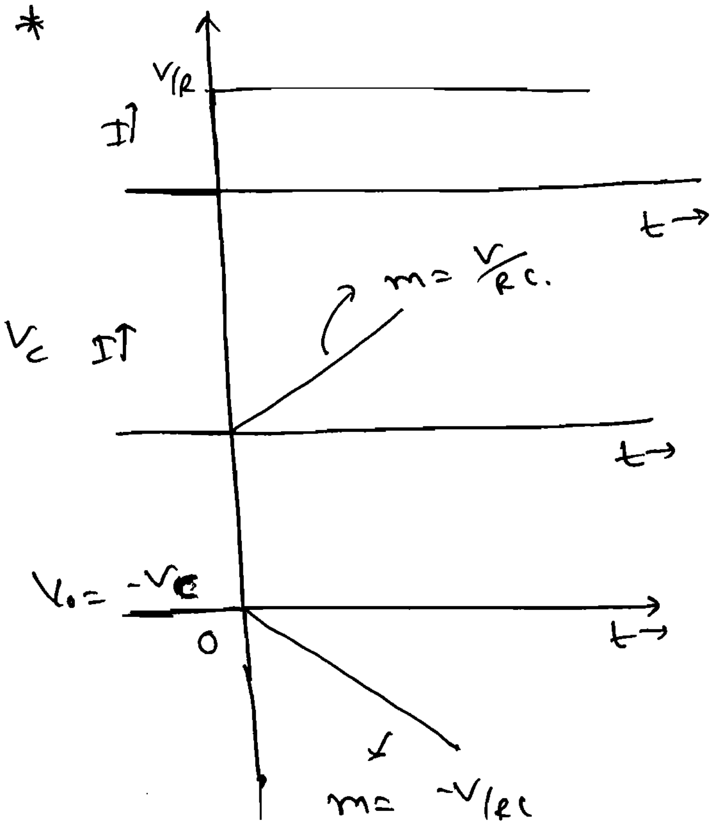
$\therefore$ $I = V/R$ = const.

$\therefore$ $V_c = \frac{1}{C}\int I\,dt = \left(\frac{I}{C}\right)t = \left(\frac{V}{RC}\right)t.$



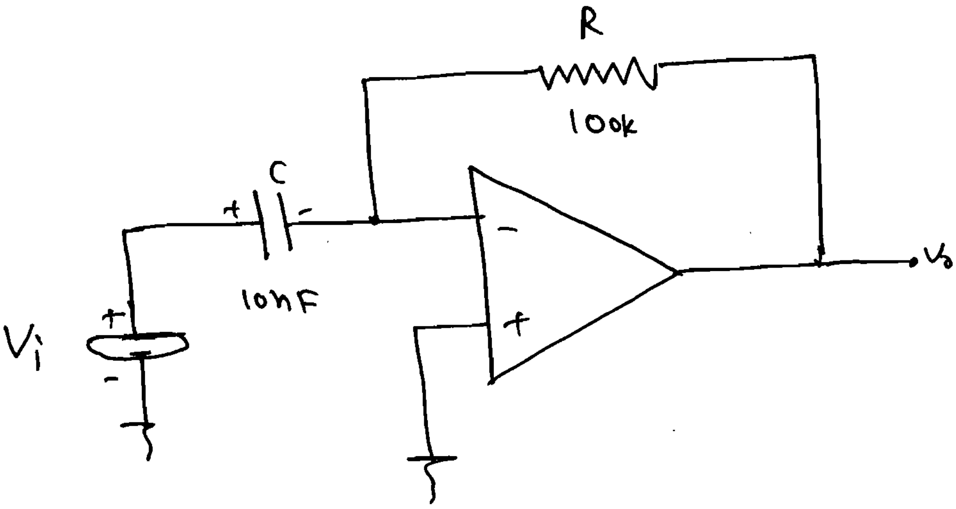
V_c	$I = \frac{5 - V_c}{1}$
0V	5A
1V	4A
3V	2A
5V	0A

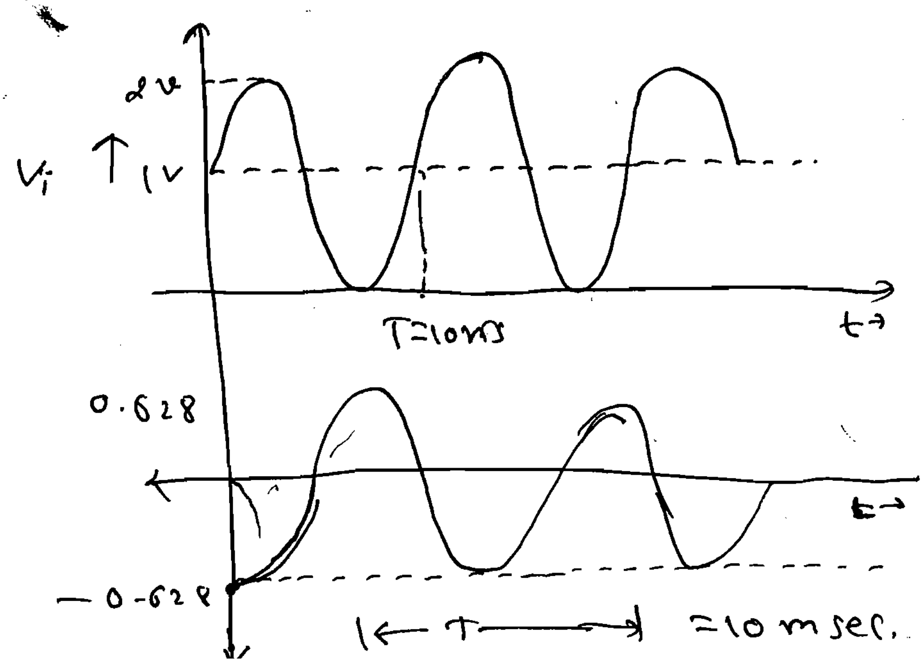




* Differentiator:

⇒





$$\frac{V_o}{V_{in}} = \frac{-R_F}{R_1}$$

$$\frac{V_o}{V_{in}} = -\frac{R_F}{(1/sC)} = -(RC)s$$

$$\boxed{V_o = (-RC)\frac{dV_i}{dt}}$$

$\therefore \quad V_i = V_{DC} + V_m \sin \omega t$

$\therefore \quad V_i = 1 + 1 \sin \frac{2\pi}{T} t$

$V_i = 1 + \sin \frac{2\pi}{10ms} t.$

$$\boxed{V_i = 1 + \sin 200\pi t}$$

$\therefore \quad V_0 = (-RC) \cdot \frac{dV_i}{dt}.$

$= \left(-100 \times 10^{+3} \times 10^{-8}\right) \times \cos 200\pi t \; (200\pi)$

$\therefore \quad V_0 = -0.628 \cos 200\pi t.$

$t = 0$

$\therefore V_0 = -0.628.$

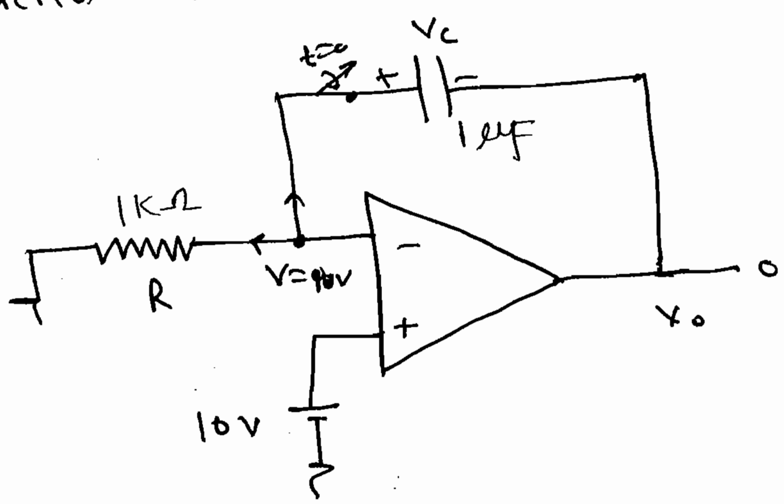
$\therefore \quad \cancel{2\pi f t} = 200\pi \cancel{t}$

$2f = \cancel{200}00$

$\therefore \quad T = 10^{-2}$

$$\boxed{T = 10ms.}$$

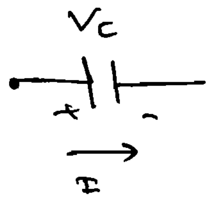
Ex-! Find the capacitor voltage at $t = 0.5ms$ it switched is closed at $t = 0$. Assume capacitor initially uncharged.



$\therefore \quad \frac{V_i - 0}{1k} = ~~V_i - V_c~~$

$\therefore \quad ~~V - V_c - V_0 = 0.~~$

$\therefore \quad ~~10 - V_c - V_0 = 0.~~$



$\therefore$

$\therefore \quad I = \frac{0-10}{1k}$

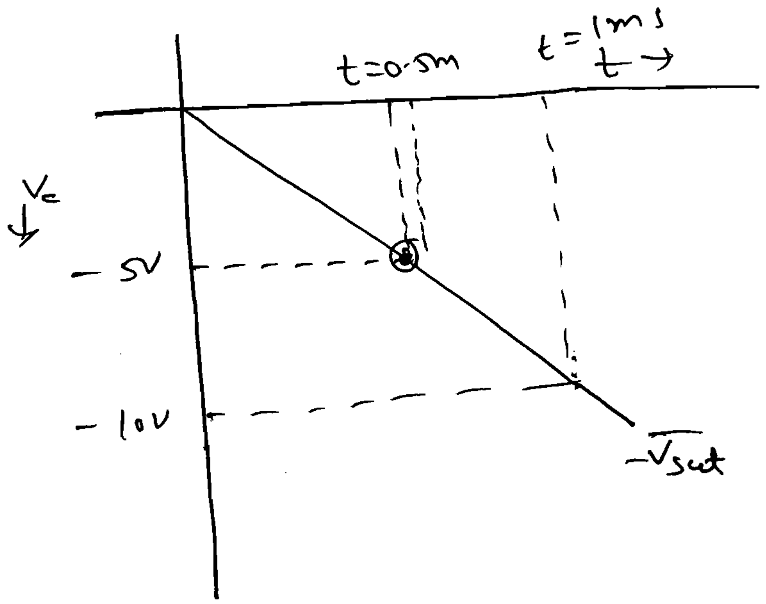
$\therefore \quad \boxed{I = -10mA}$

$\therefore \quad V_c = \frac{1}{C}\int_0^{0.5} I\,dt$

$= \frac{-10\times10^{-3}}{1\times10^{-6}} \times [t]_0^{0.5m}$

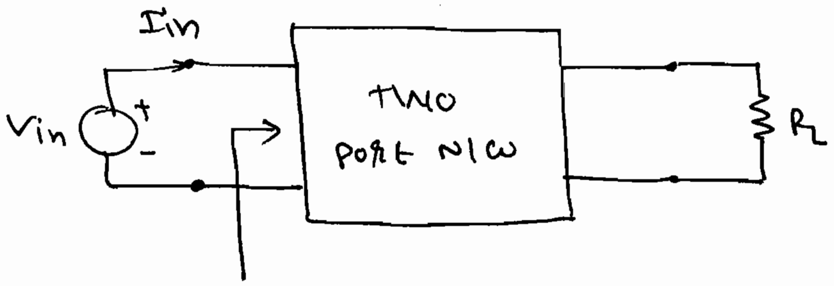
$\therefore \quad V_c = ~~10~~ -5V.$

$\therefore \quad \boxed{V_c = -5V}$



* Input and output Resistance of an amplifier using op-amp.

① Input Resistance:



$$R_{in} = \frac{V_{in}}{I_{in}}.$$

② Output Resistance:

$$R_o = \frac{1V}{I_x}$$

① OC R_L

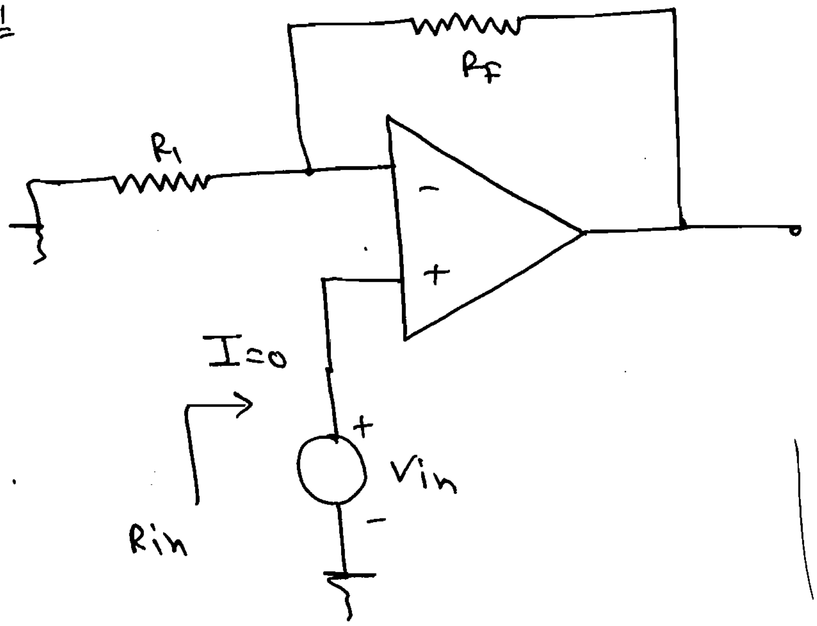
② SC V_{in}

③ Connect 1V Source at O/P terminals

$$\boxed{R_o = \frac{1V}{I_x}.}$$

*

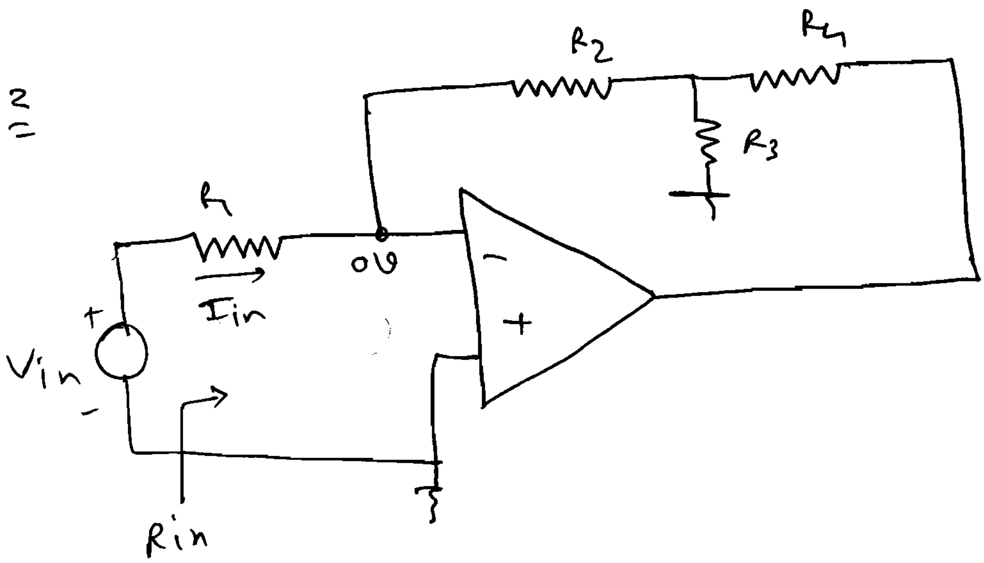
Ex-1



$$\therefore \quad R_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{0}$$

$$\therefore \quad \boxed{R_{in} = \infty.}$$

Ex-2

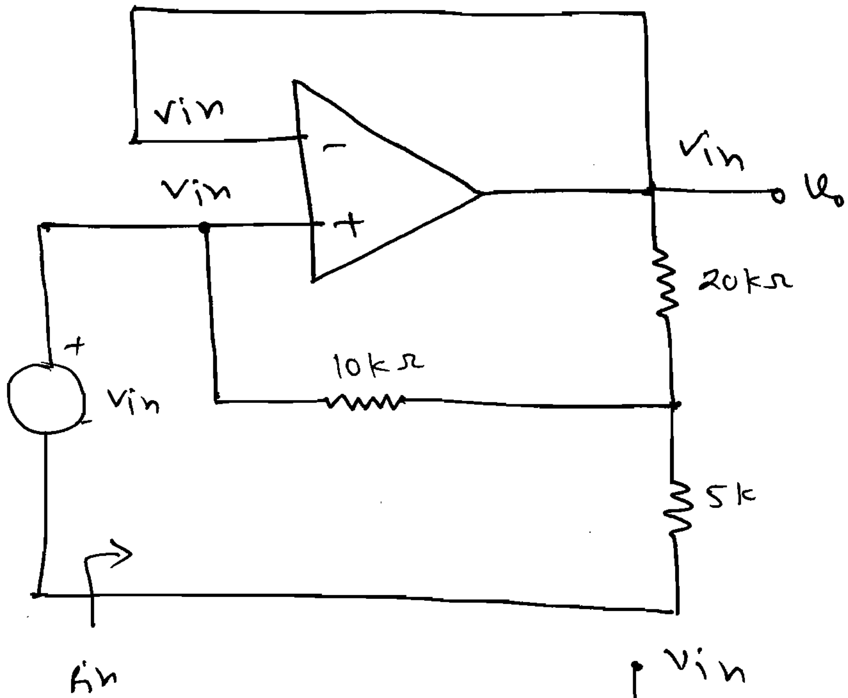


$$I_{in} = \frac{V_{in} - 0}{R_1}.$$

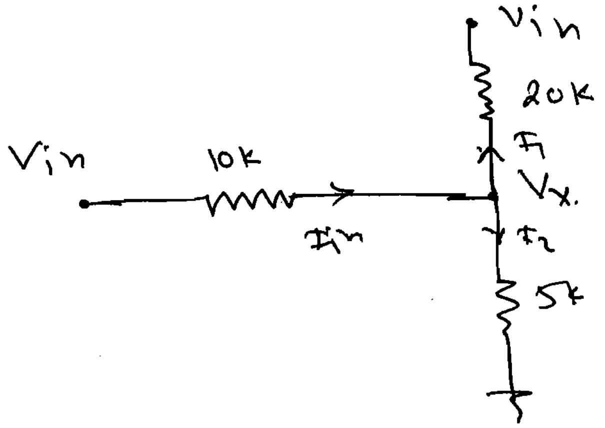
$$\therefore \quad R_{in} = \frac{V_{in}}{I_{in}}$$

$$\therefore \quad \boxed{R_{in} = R_1}$$

Ex-3



Ans:



By KCL

$\therefore \quad I_{in} = I_1 + I_2$

$\therefore \quad \dfrac{V_{in} - V_x}{10} = \dfrac{V_x - V_{in}}{20} + \dfrac{V_x}{5}.$

$\therefore \quad 2(V_{in} - V_x) = V_x - V_{in} + 4V_x.$

$\therefore \quad 7V_x = 3V_{in}$

$\therefore \quad \boxed{V_x = \dfrac{3V_{in}}{7}}$

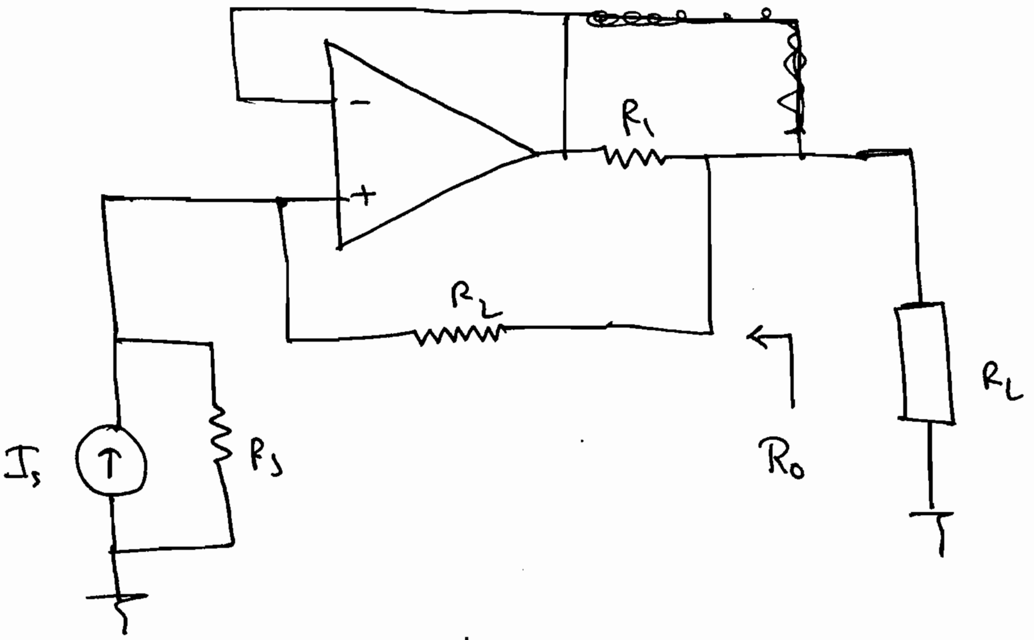
Now, $\quad I_{in} = \dfrac{V_{in} - V_x}{10}.$

$\therefore \quad I_{in} = \dfrac{V_{in} - \frac{3}{7}V_{in}}{10}$

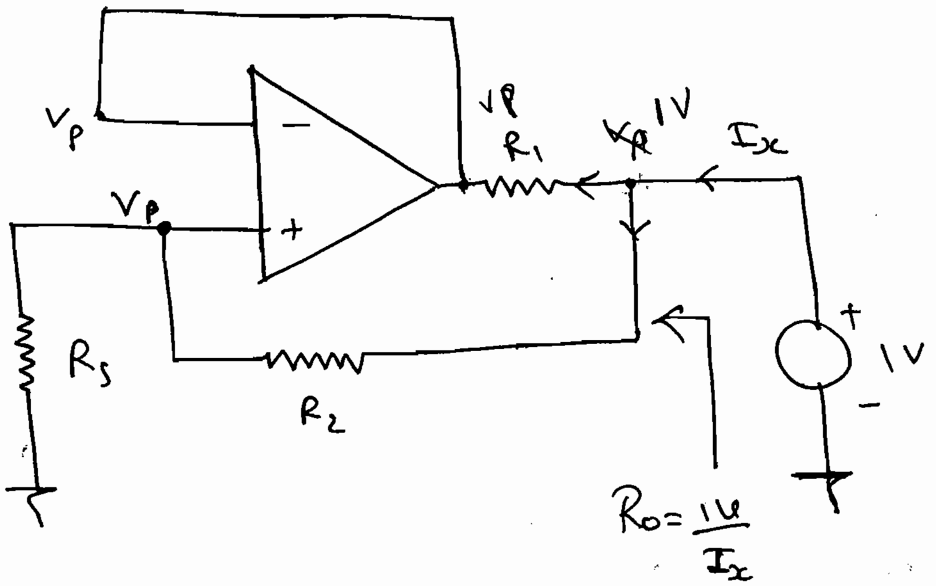
$\therefore \quad I_{in} = \frac{4}{70} V_{in}.$

$\therefore \quad R_{in} = \dfrac{V_{in}}{I_{in}} = 70/4 \text{ k}\Omega.$

Ex-1 for o/p R_o



|||



$$\rightarrow \quad V_p = \frac{R_s(1)}{R_s+R_2} \Rightarrow 1-V_p = \frac{R_2}{R_2+R_1}$$

$$I_x = \frac{1-V_p}{R_1} + \frac{1-V_p}{R_2}.$$

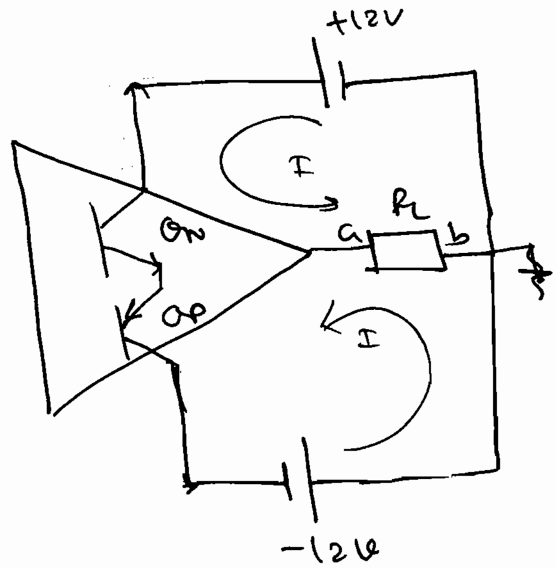
$$\therefore I_x = (1-V_p)\left[\frac{1}{R_1} + \frac{1}{R_2}\right].$$

$$\therefore I_x = \left[\frac{\cancel{R_2}}{R_2+R_s}\right]\left[\frac{R_1+R_2}{R_1 \cancel{R_2}}\right]$$

$\therefore \quad R_o = 1/I_x$

$\therefore \quad \boxed{R_o = \dfrac{R_2 + R_3}{1 + \frac{R_2}{R_1}}}$

*



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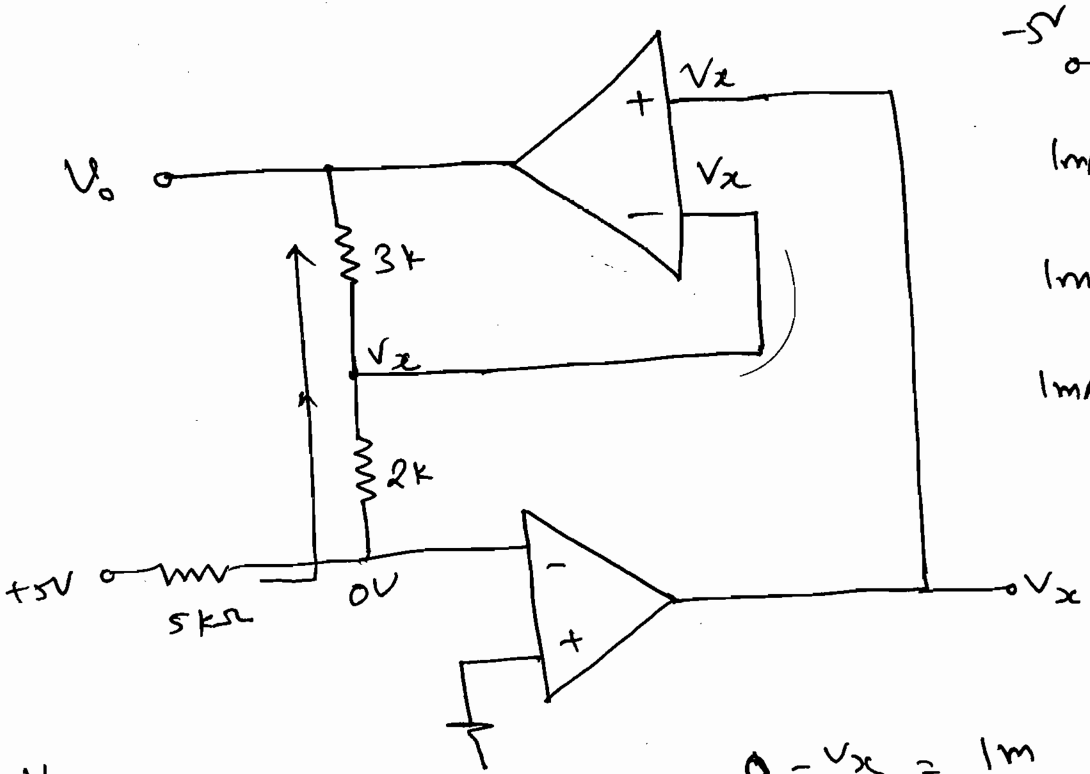
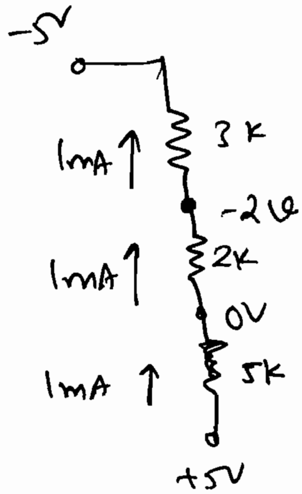
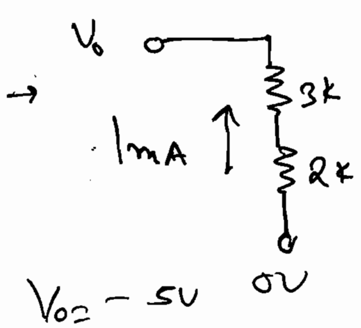


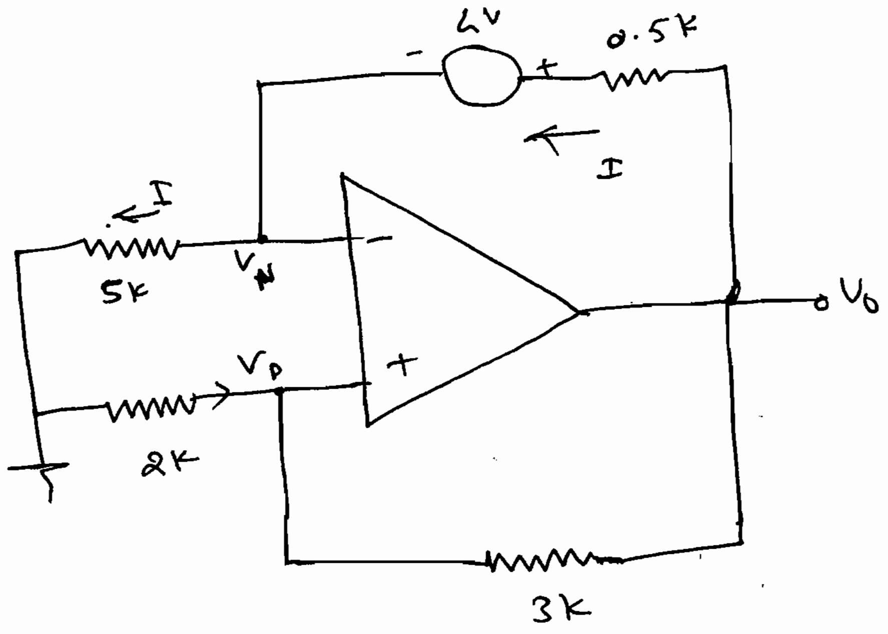




$\therefore \quad \dfrac{0 - V_x}{2K} = 1m$

$\therefore \quad \boxed{V_x = -2V}$

Ex-2



$\rightarrow$ $V_P = \frac{2}{5} V_0$.

$V_N = V_P = \frac{2}{5} V_0$.

$\therefore \quad \frac{0 - V_N}{5} = \frac{V_N + 4 - V_0}{0.5}$

$\therefore \quad -\frac{\cancel{2} V_0}{25} = \cancel{2}\left(\frac{2}{5} V_0 + 4 - V_0\right)$.

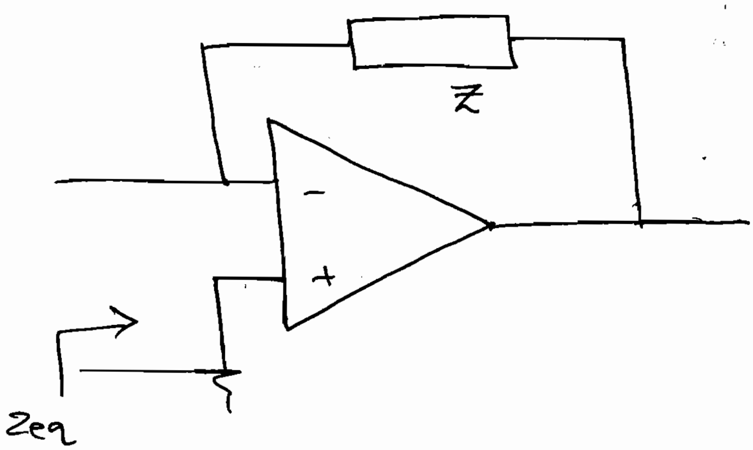
$\therefore \quad -\frac{V_0}{\cancel{25}\,5} = \frac{2V_0 + 20 - 25 V_0}{\cancel{5}}$

$\therefore \quad -V_0 = 10 V_0 + 100 - 25 V_0$.

$\therefore \quad 14 V_0 = 100$

$\therefore \quad \boxed{V_0 = \frac{50}{7} V.}$

* Miller's effect:



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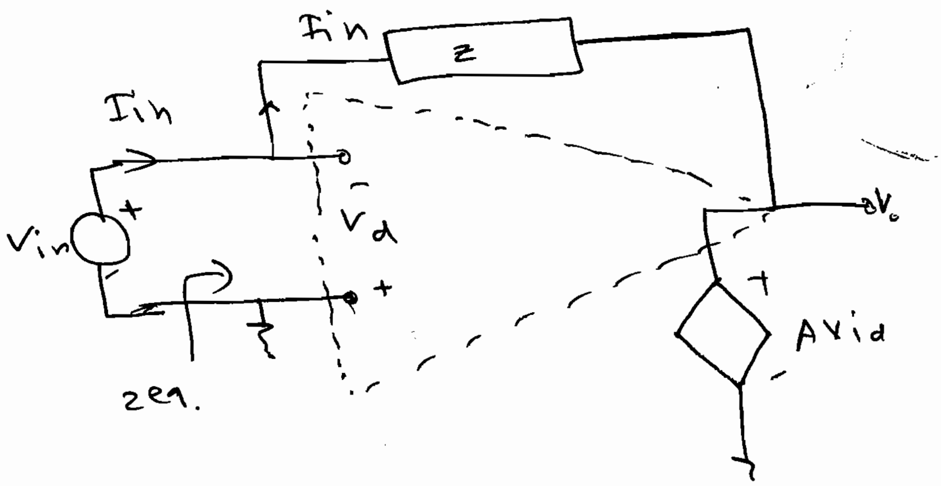


$$\rightarrow \quad V_{in} - z I_{in} - A V_{id} = 0$$

$$\therefore \quad I_{in} = \frac{V_{in} - A V_{id}}{z}$$

But, $\quad -V_{id} - V_d = 0$

$$\therefore \quad V_d = -V_{in}$$

$$\therefore \quad I_{in} = \frac{V_{in} + A V_{in}}{z}.$$

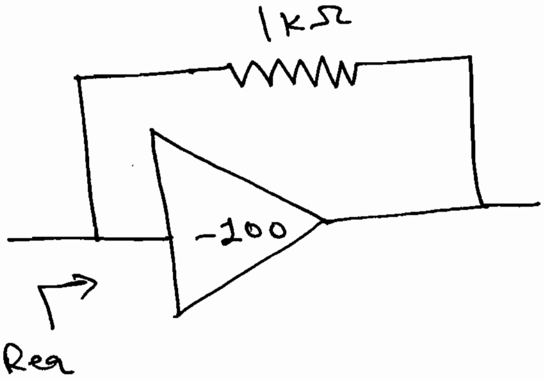
$$\therefore \quad \boxed{Z_{eq} = \frac{V_{in}}{I_{in}} = \frac{z}{1+A}}$$

NOTE: Miller's effect is seen only for inverting amplifier.

e.g. \ CE amplifier suffers from miller's effect.

- There is no miller's effect for CB and CC amplifier.

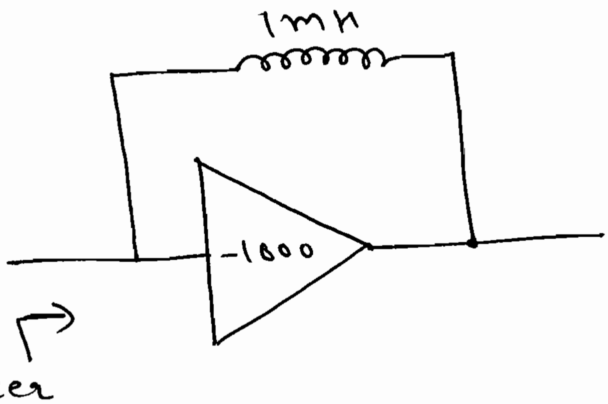
*



$$\therefore \; Z_{eq} = \frac{\cancel{Z}}{}$$

$$R_{eq} = \frac{R}{1+A} = \frac{1k}{1+100} = \frac{1000}{101} = 10\,\Omega$$

*

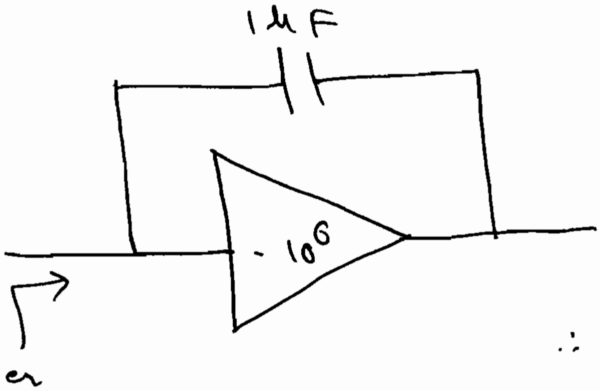


$$\therefore Z_{eq} = \frac{Z}{1+A} = \frac{j\omega L}{1+1000} = \frac{sL}{1+1000}$$

$$\therefore sL_{eq} = \frac{sL}{1+1000} =$$

$$\therefore \boxed{L_{eq} = \frac{\frac{1}{1000}}{1+1000} = 1\,\mu H}$$

*



$$Z_{eq} = \frac{Z}{1+A} =$$

$$\therefore \frac{1}{sC_{eq}} = \frac{\frac{1}{sC}}{1+A}$$

$$\therefore C_{eq} = \frac{\cancel{c}\,1+A}{\cancel{c}}$$

$$\therefore C_{eq} = \frac{10^{-6}}{10^{+6}}$$

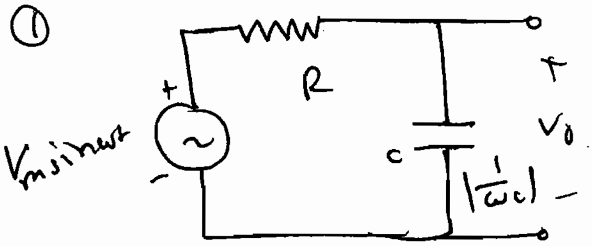
$$\boxed{C_{eq} = \cancel{10^{-12}}\,F}$$

$$\boxed{C_{eq} = 1\,F}$$

$$\therefore \boxed{C_{eq} = (1+A)\,C}$$

miller's multiplication

①



$\tau = Rc$

$\tau = R_{th} C.$

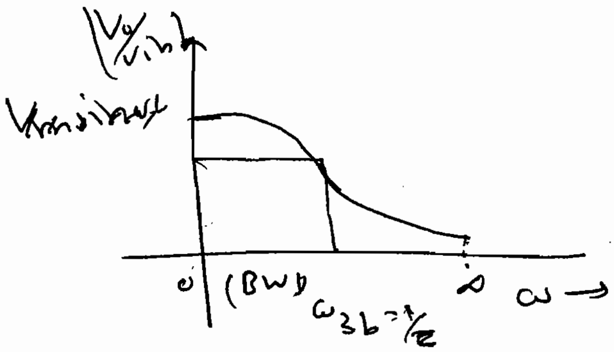
$\therefore \left|\frac{1}{2\pi f c}\right|$

as $f \to$ high $\left|\frac{1}{2\pi f c}\right| = 0$ so S.C.

so, $V_0 = 0$.

$f \to$ Low $\left|\frac{1}{2\pi f c}\right| = \infty$ so O.C.

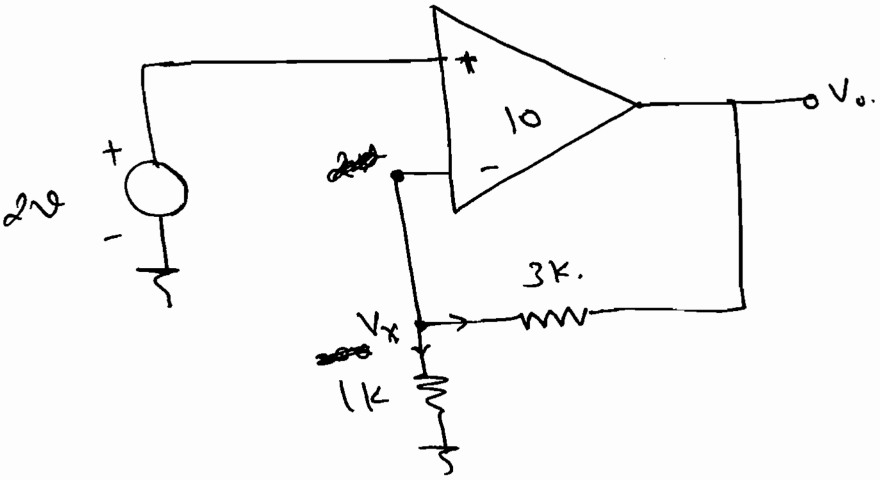
$\therefore$ so, $V_0 = \sin\omega t$.



$\therefore \quad BW = \frac{1}{\tau} = \frac{1}{RC}.$

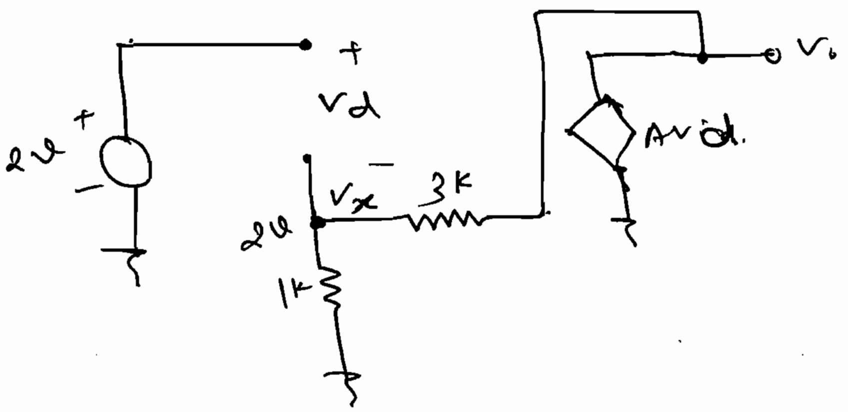
$\therefore \quad C_{eq} \uparrow \Rightarrow \tau \uparrow \Rightarrow BW \downarrow.$

Ex-1



$A_{OL} = 10$ find $V_o = ?$

|||



$\therefore V_x = V_0 \left(\frac{1}{4}\right)$.

$\therefore V_o = 10 V_d$.

and $V_d = 2 - V_x$

$\therefore V_d = 2 - \left(\frac{V_o}{4}\right)$.

$\therefore V_o = 20 - \frac{5V_o}{2}$.

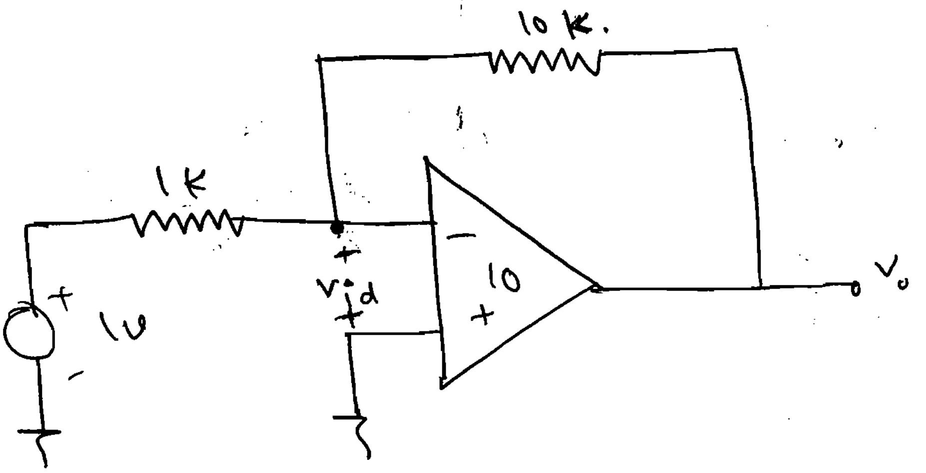
$\therefore \frac{7V_o}{2} = 20$

$\therefore \boxed{V_o = \frac{40}{7}}\ V$

$\therefore \quad A_v = \frac{V_o}{2V}$.

$\therefore \boxed{A_v = \frac{20}{7}}$, $A_{OL} = 10$.

Ex 2 Find V_o. $A_{OL} = 10$.



$$\frac{1 + V_{id}}{1k} = \frac{-V_{id} - V_o}{10k}.$$

$\therefore$ $V_o = A V_{id}$.

$\therefore$ $V_o = 10 V_{id}$

$$\therefore \frac{1 + \frac{V_o}{10}}{1k} = \frac{-\frac{V_o}{10} - V_o}{10}$$

$$\therefore 10 + V_o = \frac{-V_o - 10V_o}{10}$$

$\therefore$ $\cancel{100 + 10V_o = V_o - 10V_o}$

$\cancel{V_o = 100V}$.

$\cancel{100 + V_o = V_o - 10V_o}$

$\boxed{\cancel{V_o = -10}}$

$\therefore$ $100 + 10V_o = -V_o - 10V_o$.

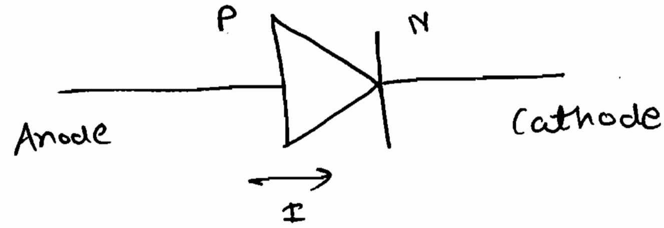
$$\frac{100}{21} = -21V_o$$

$\therefore$ $\boxed{V_o = -4.98\ V.}$

$21 \overline{)100}$ 4.8
84
160

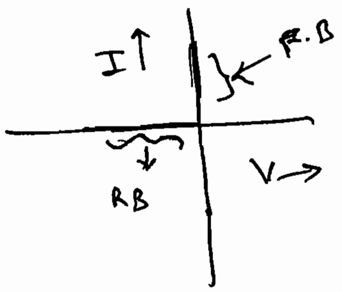
☆ Diode Applications:

→



→ A diode is forward bias when anode is more +ve than cathode.

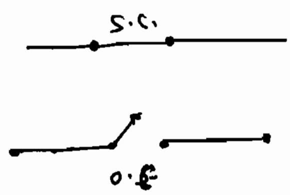
→



FB $I > 0 \Rightarrow V = 0$

RB $V < 0 \Rightarrow I = 0.$

Models



piece-wise Linear model.

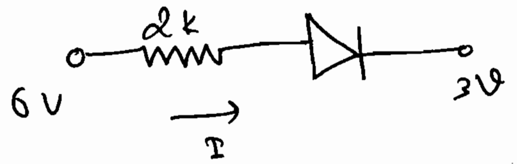
if $I = +ve \rightarrow$ F.B.

$I = -ve \rightarrow$ R.B.

But I never -ve so

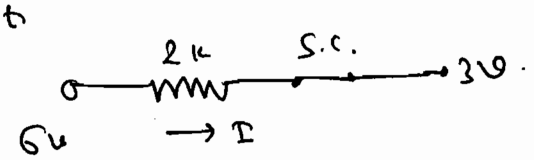
$I = 0 \Rightarrow$ R.B.

Ex - 1 Check whether Diode is F.B. or not. also find the value of current flow:

① 

⇓

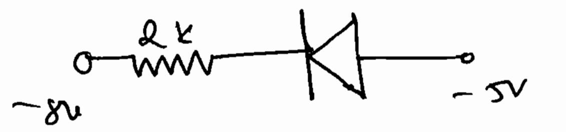
Let



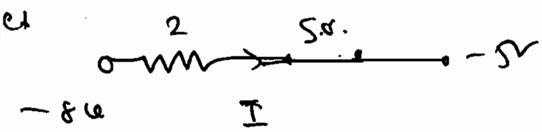
$\therefore I = \frac{6-3}{2}$

$\therefore \boxed{I = 1.5 \text{ mA}} > 0$

so, $\boxed{\text{F.B.}}$

② 

Let



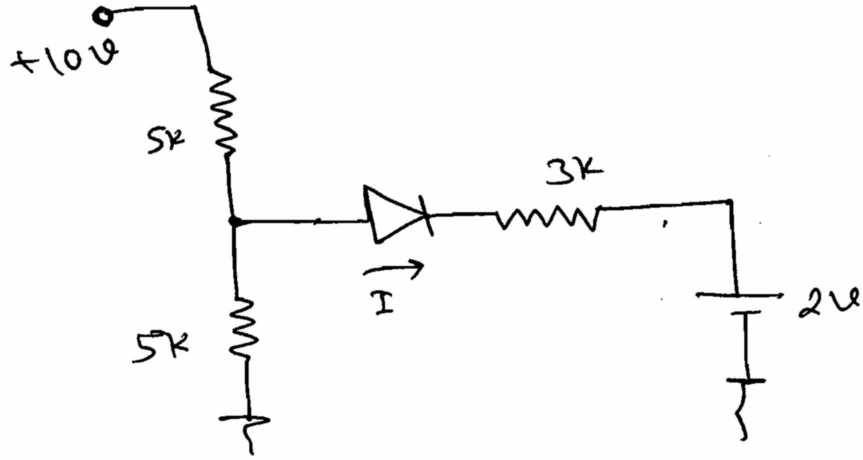
$\therefore I = \frac{+8 - 5}{2}.$

$\therefore I = +1.5 \text{ mA}$

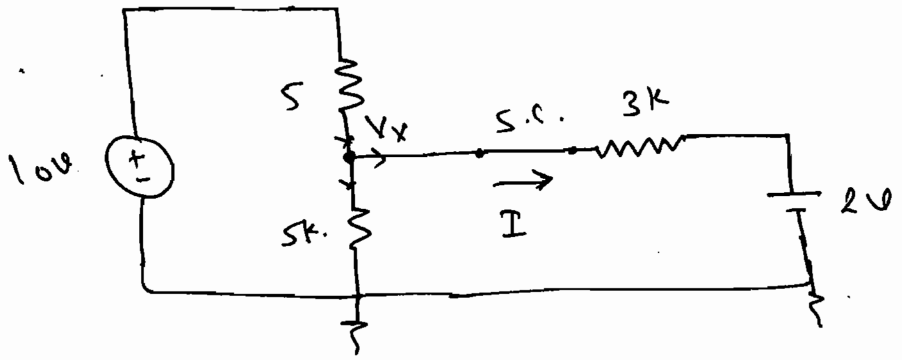
so, R.B.

and $\boxed{\cancel{I \neq 0}}$

Ex-3



⇓



$$\therefore \frac{10 - V_x}{5} = \frac{V_x}{5} + \frac{V_x - 2}{3}.$$

$$\therefore 2 - \frac{V_x}{5} = \frac{V_x}{5} + \frac{V_x}{3} - 2/3.$$

$$2 + 2/3 = \frac{2V_x}{5} + \frac{V_x}{3}.$$

$$\therefore \frac{8}{\cancel{3}} = \frac{6V_x + 5V_x}{\cancel{15}\ 5}.$$

$$\boxed{V \quad \frac{40}{11} = V_x}$$

$$\therefore I = \frac{V_x - 2}{3k}$$

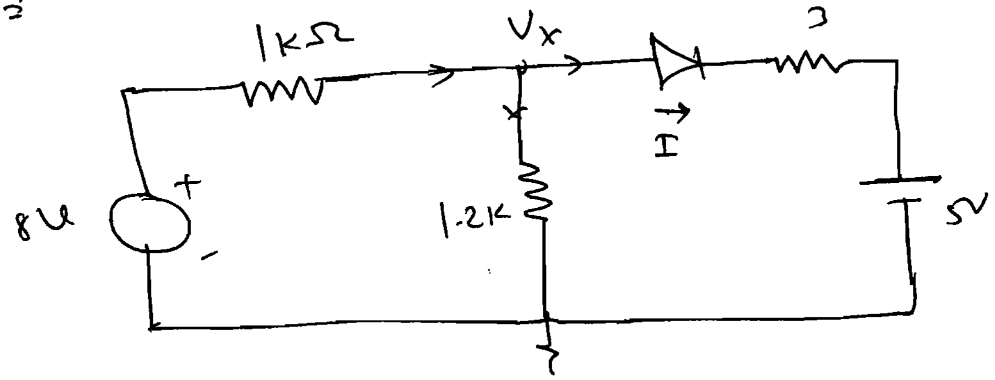
$$\therefore I = \frac{\frac{40}{11} - 2}{3k}$$

$$I = \frac{18}{3}$$

$$\therefore \boxed{I = \frac{6mA}{11}}$$

S, FB.

Ex-4



$$\rightarrow \quad \frac{8 - V_x}{1} = \frac{V_x}{1.2} + \cancel{I}\cdot\frac{V_x - 5}{3}.$$

$$\therefore \quad 8 - V_x = \frac{5V_x}{6} + \frac{V_x}{3} - 5/3.$$

$$\therefore \quad 8 + \frac{5}{3} = \frac{7V_x}{6} + V_x.$$

$$\therefore \quad \frac{29}{\cancel{3}} = \frac{13V_x}{\cancel{6}2}$$

$$\therefore \quad \boxed{\frac{58}{13} = V_x.}$$

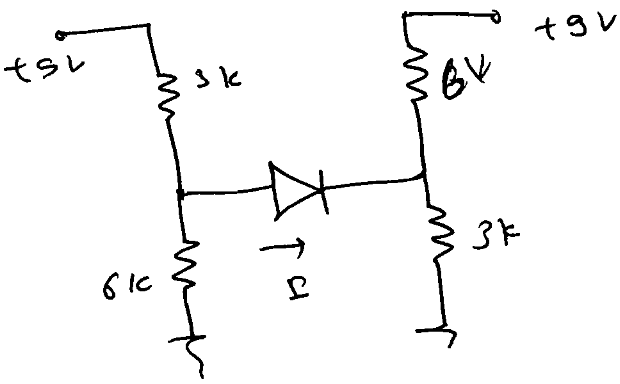
$$\therefore \quad I = \frac{V_x - 5}{3k}$$

$$\therefore \quad I = \frac{\frac{58}{13} - 5}{3k}.$$

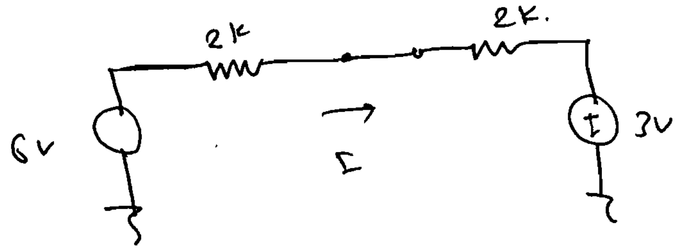
$$\therefore \quad \boxed{I = \frac{-7}{39}\ mA.}$$

So, R.B. $\boxed{I = 0}$

Ex-5



$\Rightarrow$

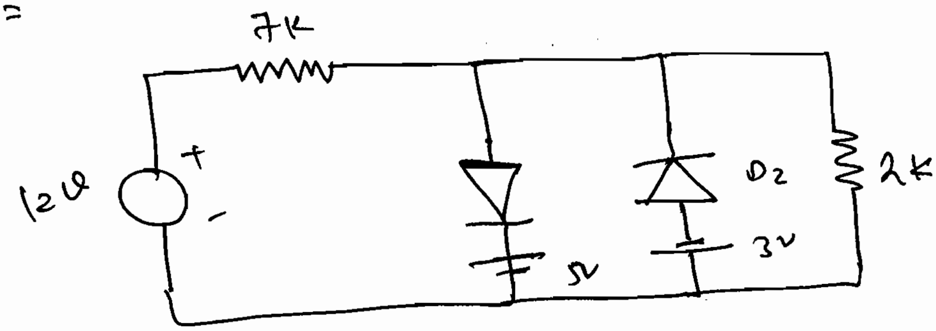


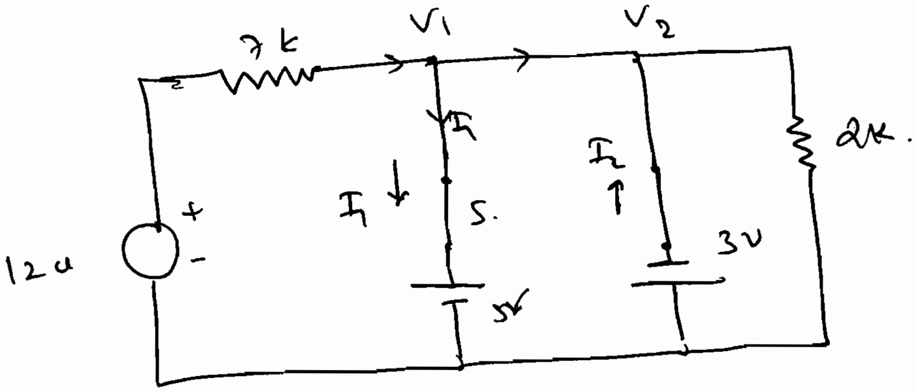
$$I = \frac{6-3}{4}$$

$$I = 3/4$$

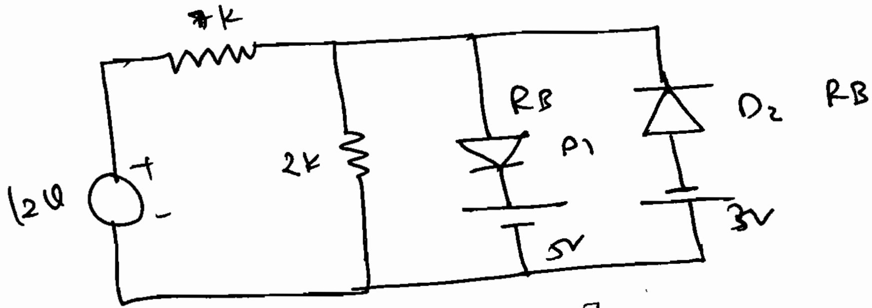
$$I = 0.75\ mA.$$

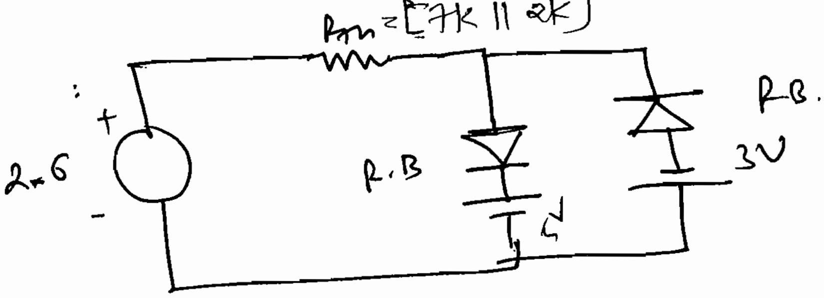
Ex-2





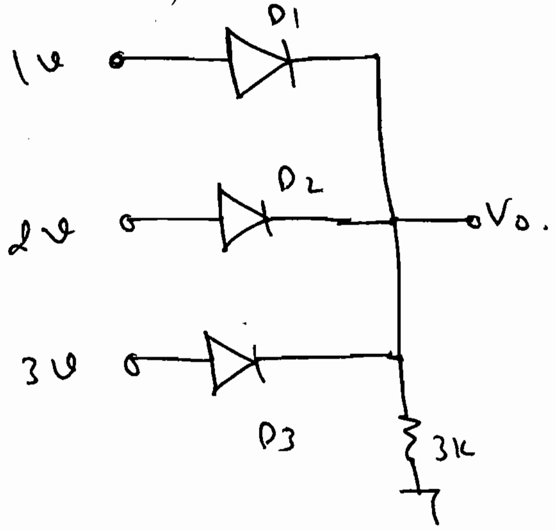
→ $\frac{V_2 - V_1}{7}$





Both are R.B.

Ex-1 Find Vo, Diode is ideal

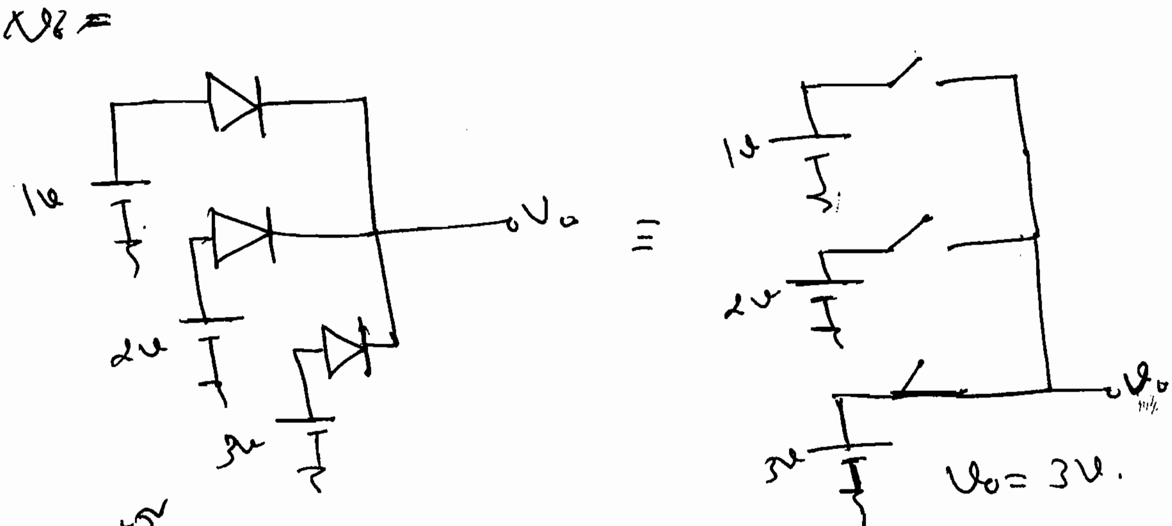


$$I_d = I_s e^{V_D/V_T} \quad \text{exp operation}$$

$$V_D = V_t \ln\left[\frac{I_D}{I_s}\right]$$

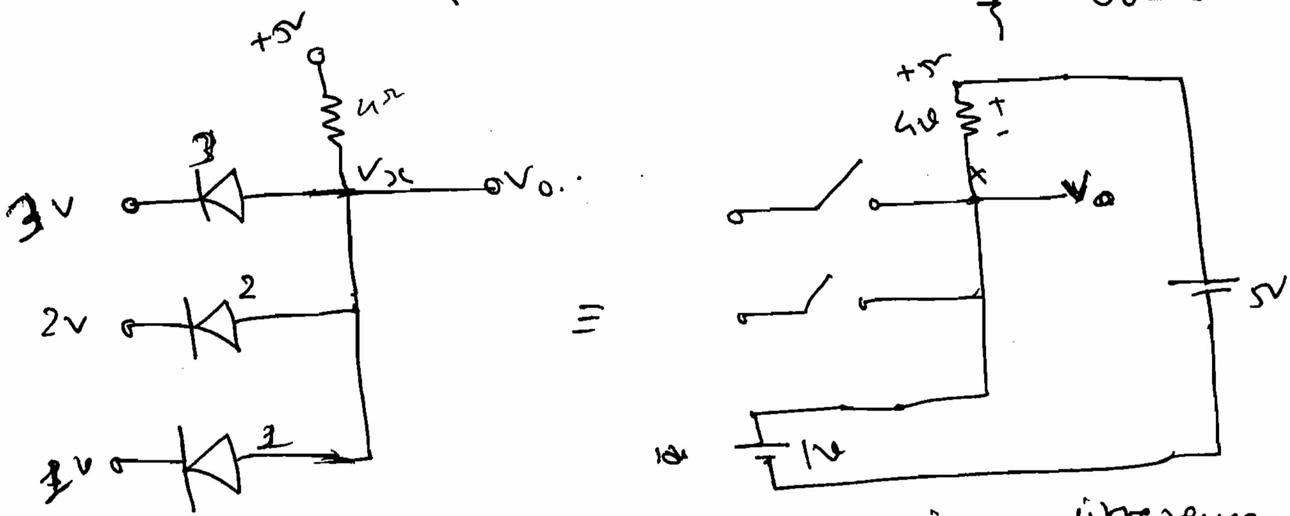
log operation

→ ①



$V_o = 3V$.

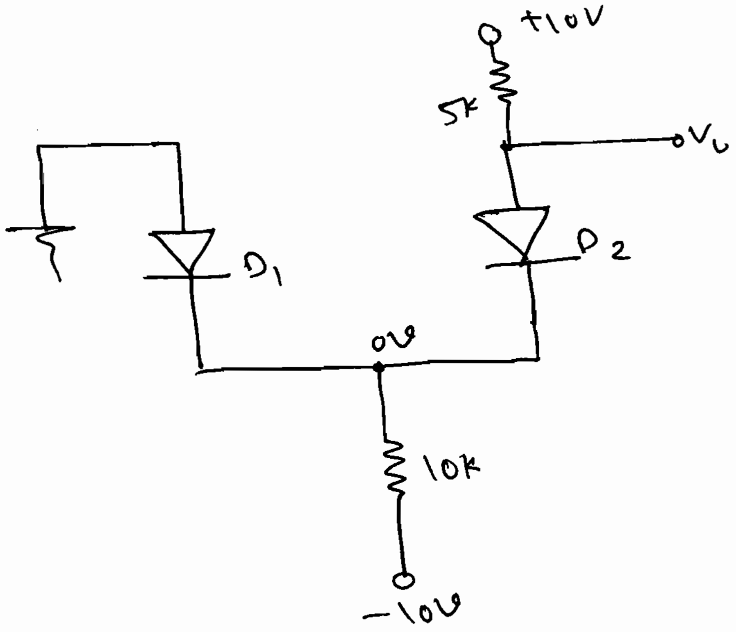
Ex-2



→ 1V Diode experience more potential difference so, it is on ~~adn~~ and D_2 D_3 is off.

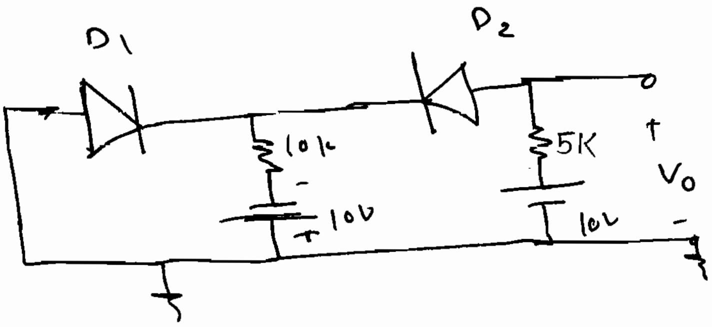
and $V_o = 1V$.

Ex-2

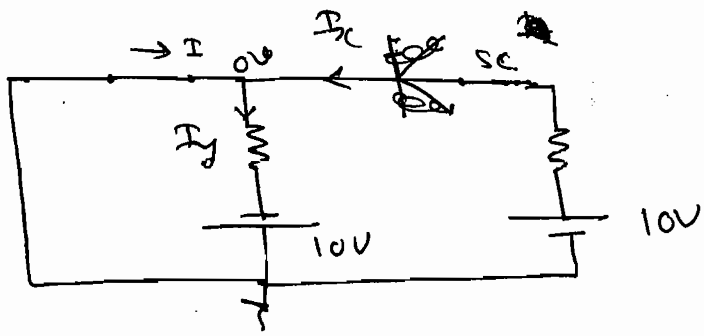


|||

⇒



Ans: Let <u>Test- D_1</u>

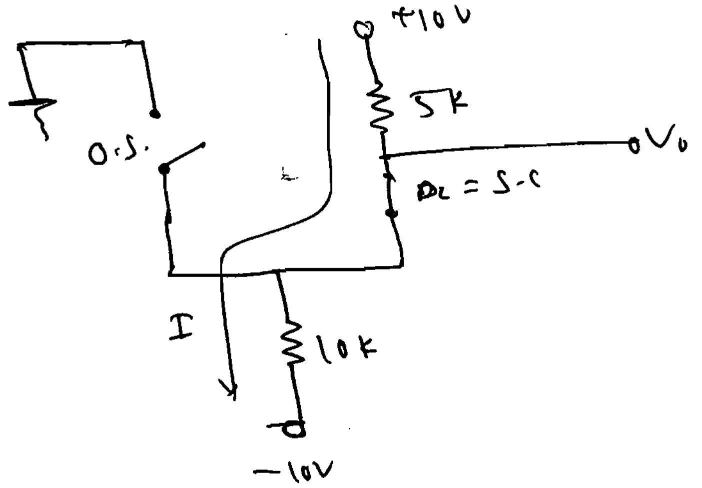


$\therefore \quad I = I_y - I_x.$

$$I = \frac{0-(-10)}{10k} - \left[\frac{10-0}{5k}\right].$$

$\therefore \quad I = -1mA$ (Neg).

$\therefore$ Diode D_1 is in RB.



$$\therefore \frac{V_0 - (-10)}{10} = I.$$

$$\therefore V_0 + 10 = 10I$$

$$\therefore V_0 = \frac{40}{3} - 10$$

$$\therefore \boxed{V_0 = \frac{10}{3}\ V.}$$

$$\therefore I = \frac{10-(-10)}{15}$$

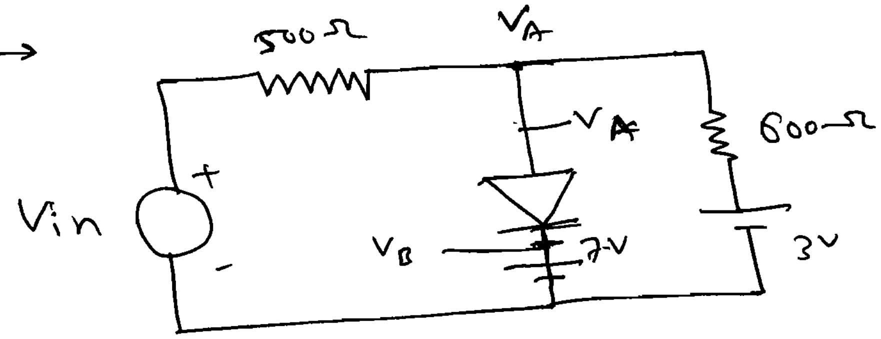
$$I = \frac{20}{15}.$$

$$\therefore I = \frac{4}{3} = 1.33\ mA.$$

$\therefore$ So, D_2 is F-B.

Ex: Find the minimum voltage Vin ~~to~~ for Diode to be FB.

→

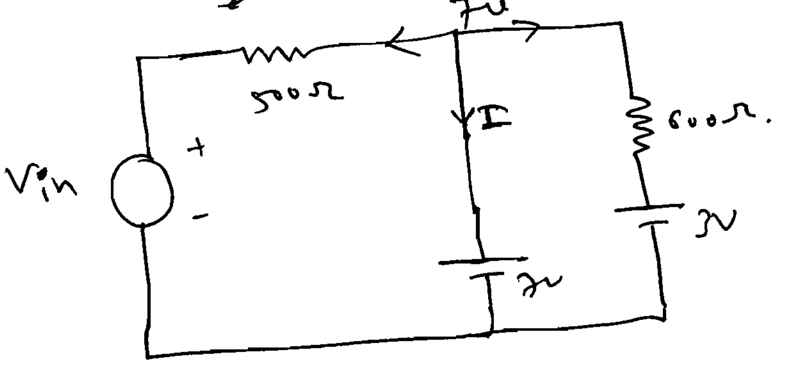


for F-B.

$$\therefore \boxed{V_A - V_B > 0}$$

V_A -

$\therefore \frac{V_{in} - V_A}{500}$



$\therefore$ Vin = 10.33 for I = 0⁺

$\therefore$ So Diode D_1 is in FB when $I > 0$.

$$\rightarrow \boxed{V_{in} > 10.33\ V.}$$

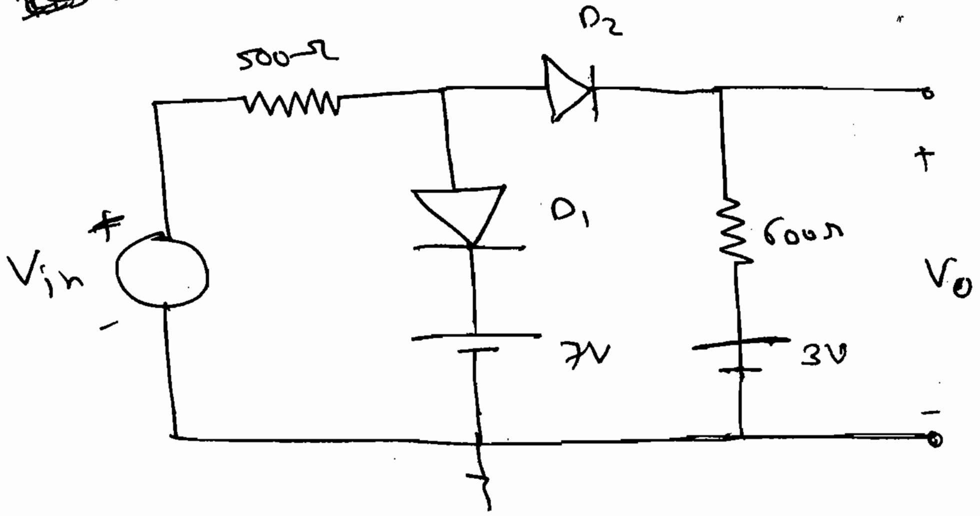
$$\frac{7 - V_{in}}{500} + I + \frac{7-3}{600} = 0.$$

Sub $I = 0^+$

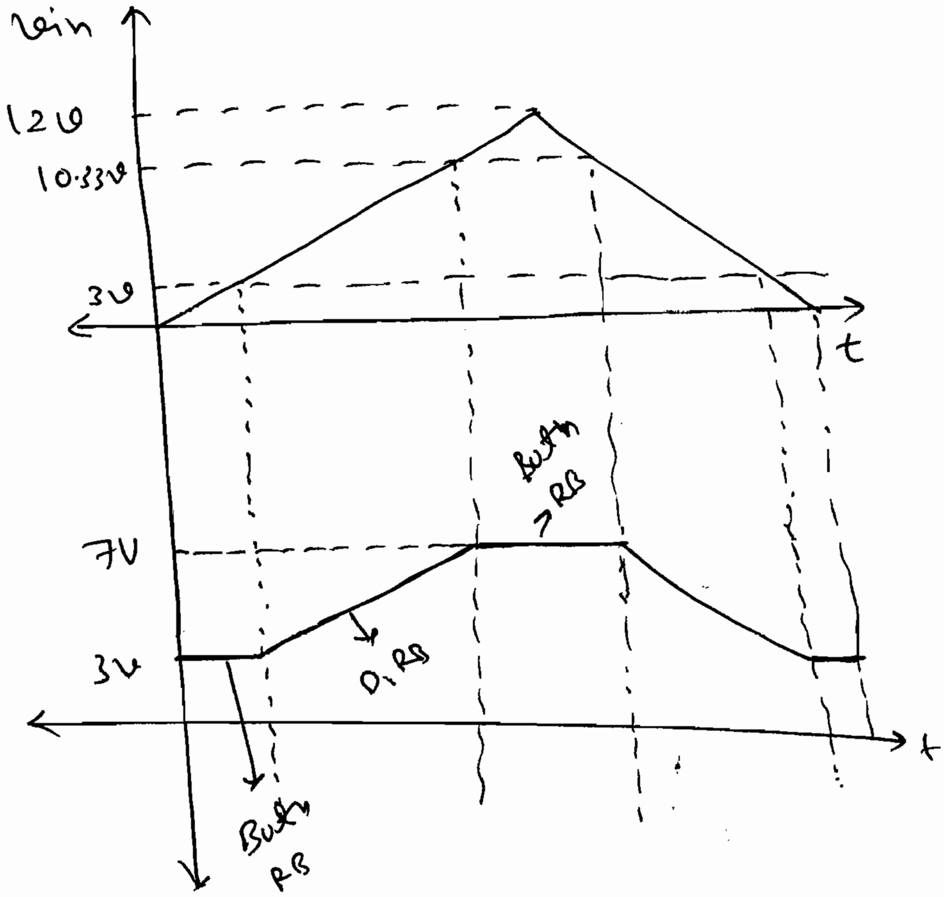
$$\therefore \frac{7 - V_{in}}{500} + \frac{7-3}{600} = 0$$

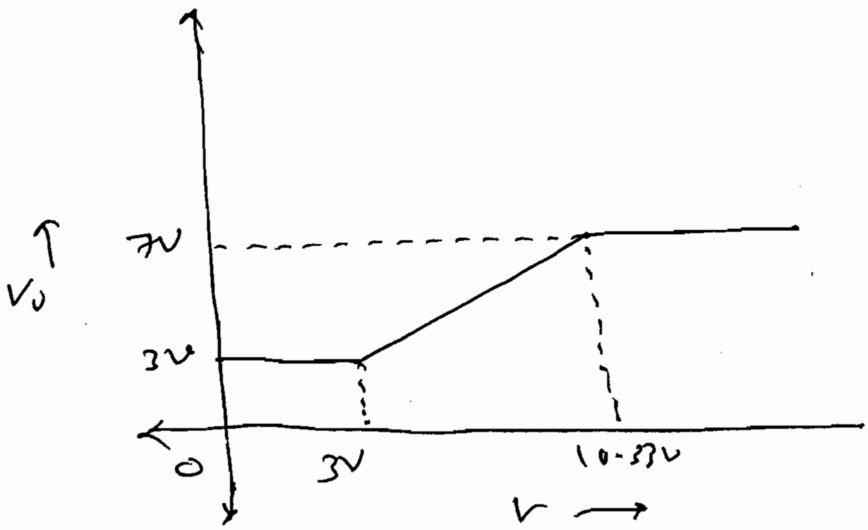
~~EDC~~ & DSC

Ex-1



Ans:

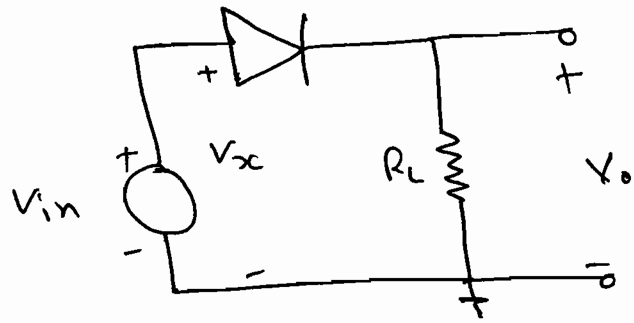




Clippers or Clipping circuits : [limiters]

→ Clipper is a circuits which cuts the portion of the required waveform.

*

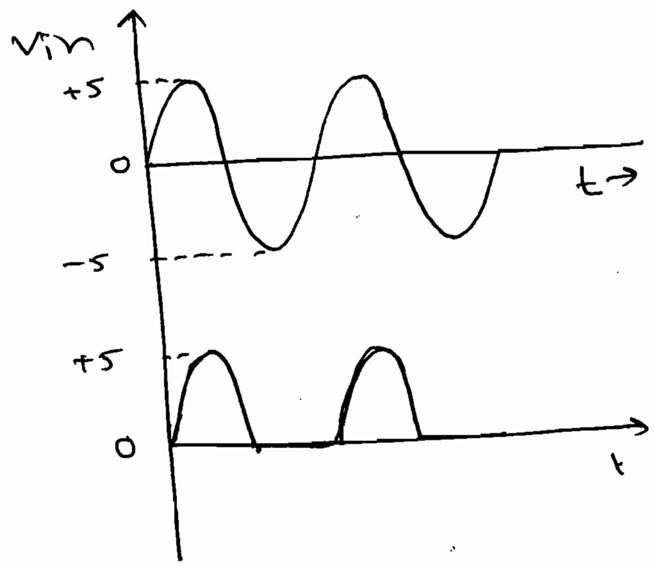


$\therefore V_x = V_{in}$

$\therefore V_{in}$ range : -5 to $+5$

V_x range : -5 to $+5$

V_o range : 0 to $+5$.



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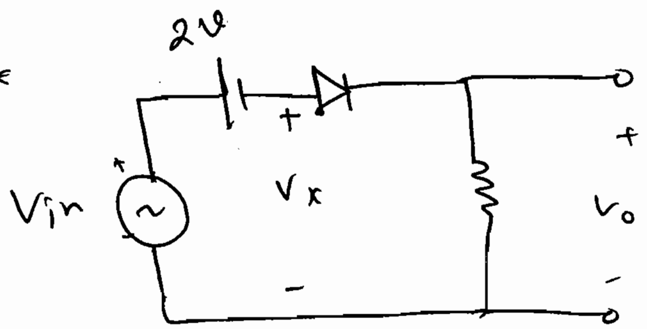


$\therefore V_x = V_{in} - 2V$.

$\therefore$ V_{in} range : -5 to $+5V$.

V_x range : -7 to $3V$.

V_o range : 0 to $3V$.

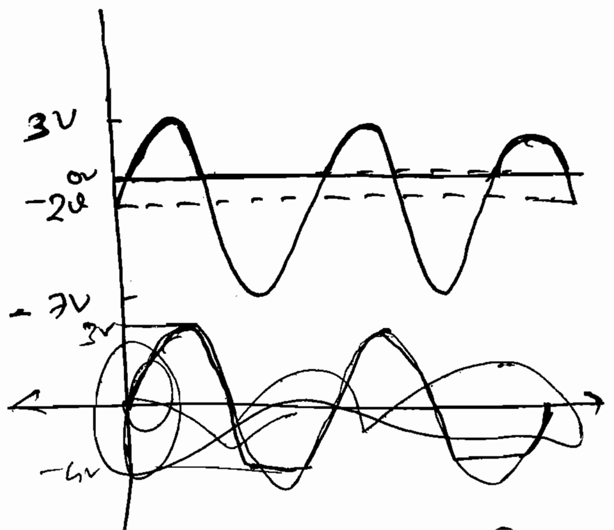
$\therefore V_o = V_{in} - 2V$.

$V_{in} > V_A - V_B$.

$V_{in} > -2 - 0$

$V_{in} > -2 \rightarrow$ F.B.

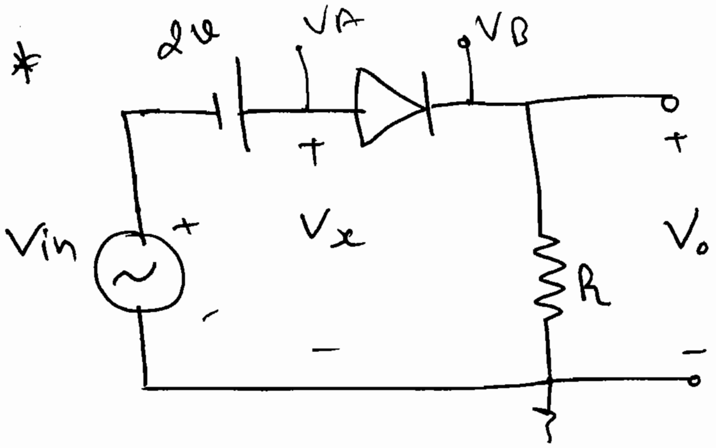
$-2 < V_{in} < 5 \rightarrow$ F.B.



$V_o = V_{in} - 2$

$-4 < V_o < +3$.

*

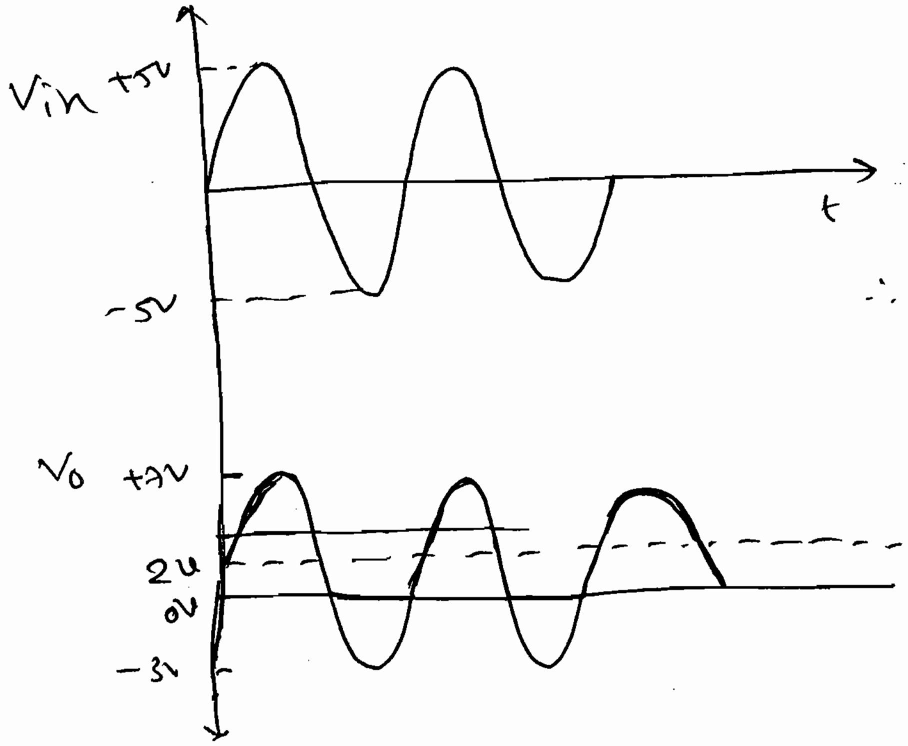


$V_x = V_{in} + 2.$

V_{in} range: -5 to $+5$ V

V_x range: -3 to $+7$ V.

V_o range: 0 to 7 V.



$V_{in} > V_A - V_B$

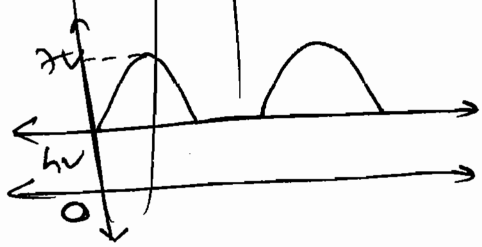
$V_{in} > 2 - 0$

$V_{in} > 2 \rightarrow$ F.B.

$2 < V_{in} < 5 \rightarrow$ F.B.

$V_o = V_{in} + 2V.$

$\therefore \boxed{0 < V_o < 7V}$



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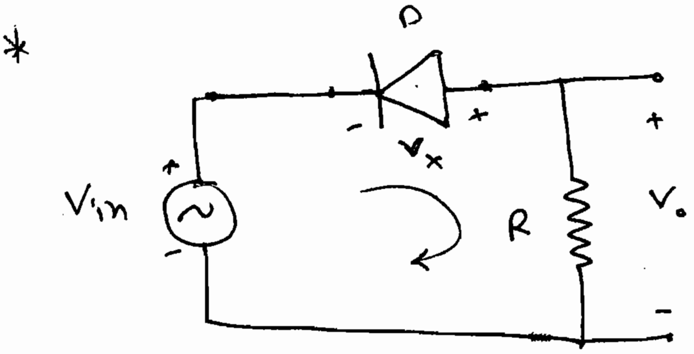


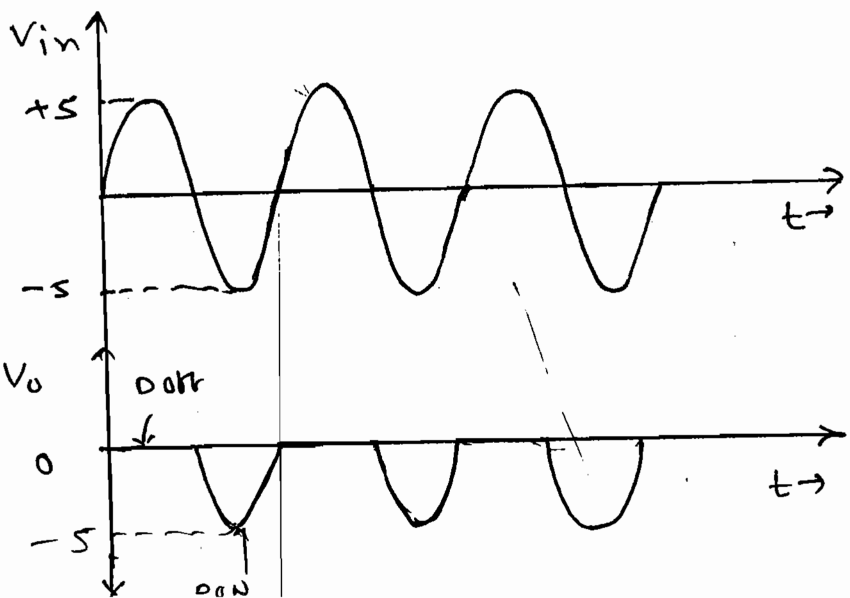
$V_{in} + V_x = 0.$

$\therefore V_x = -V_{in}.$

V_{in} range: -5 to $+5$

V_x range: 5 to -5.

V_o range: 0 to -5.



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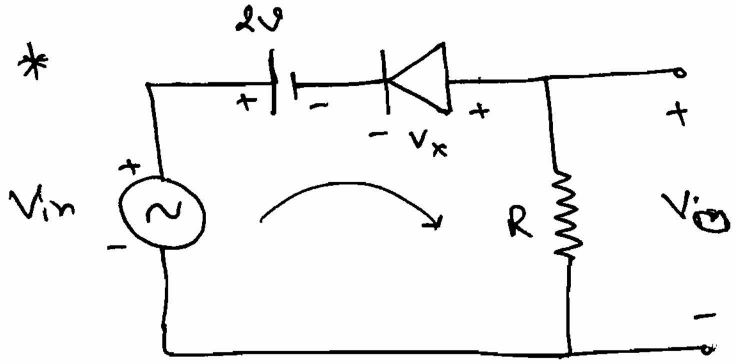


$V_{in} - 2 + V_x = 0$

$\therefore\ V_x = 2 - V_{in}$.

$\therefore V_{in}$ range: -5 to $+5$ V

V_x Range: 7 to -3.

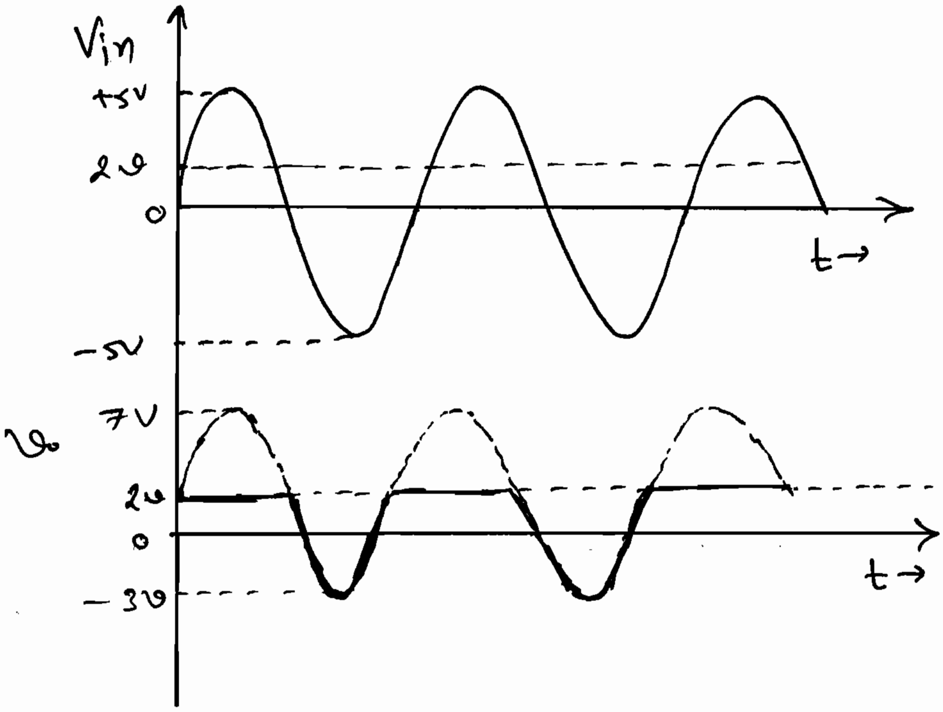
V_o Range: ~~0 to −3.~~ -7 to 0

$V_x > 0$

$2 - V_{in} > 0$

$V_{in} < 2V$.

for F.B.



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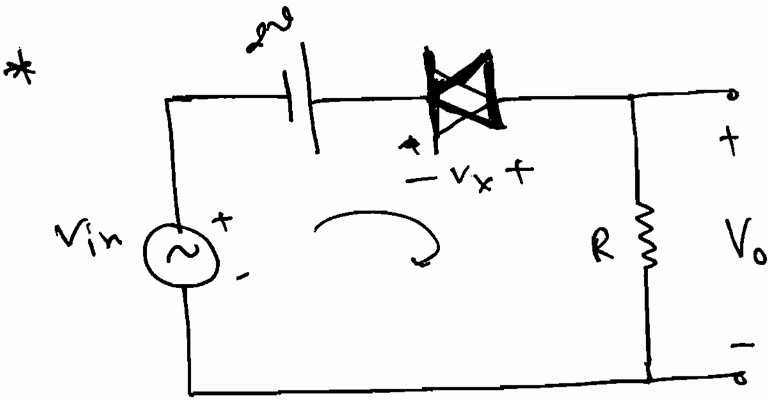


$V_{in} + 2V + V_x = 0$

$\therefore\ V_x = -V_{in} - 2V$

V_x range: 3 to -7V.

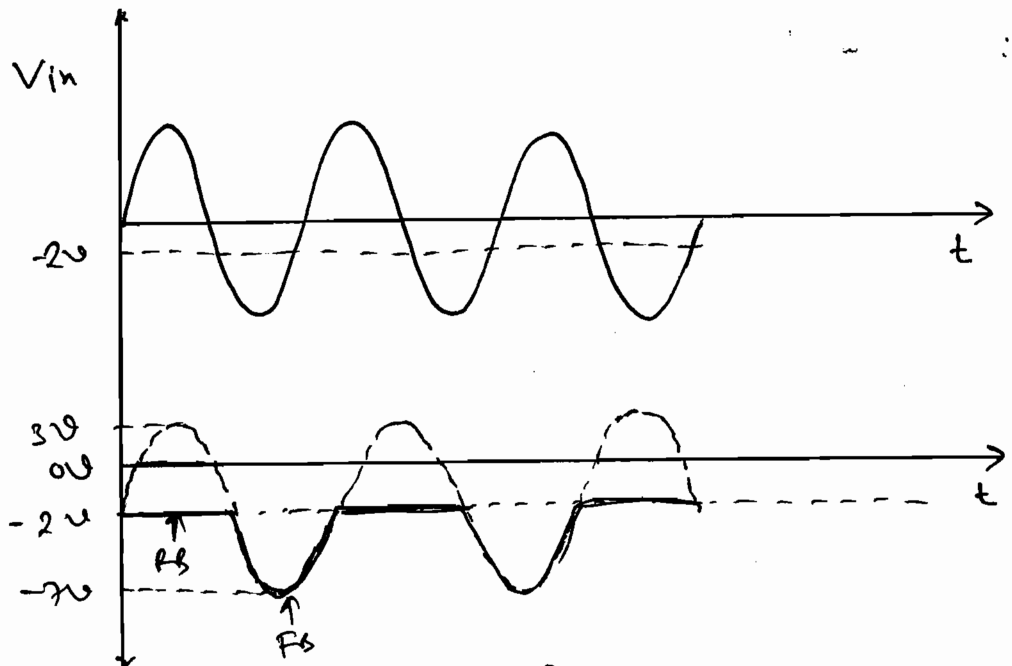
V_o range: 0 to -7 V.

$V_x > 0$

$\therefore\ -V_{in} - 2V > 0$

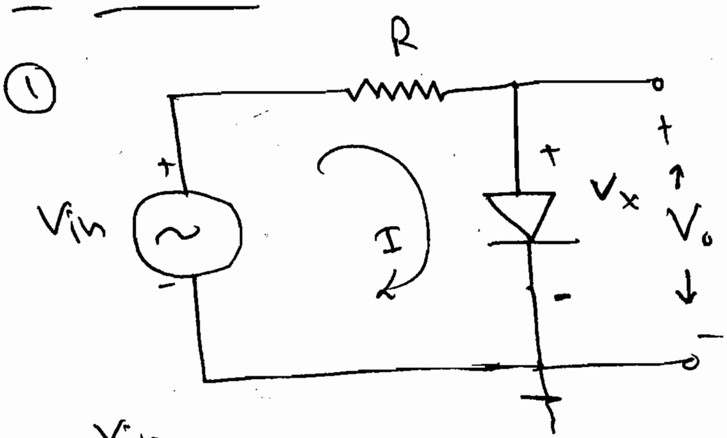
$V_{in} < -2V$.

$V_o = 0$ to -3V.



* Sketch V_o.

(1)



$V_{in} - V_x = 0$

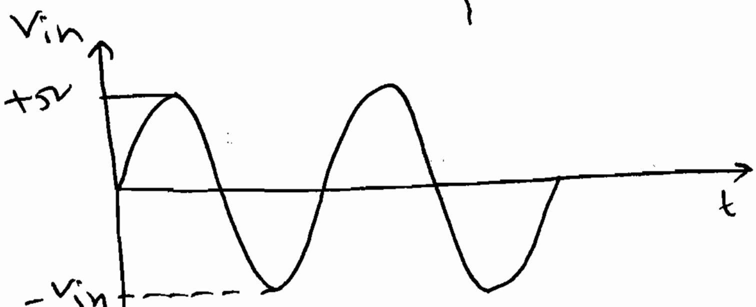
$\therefore V_x = V_{in}$.

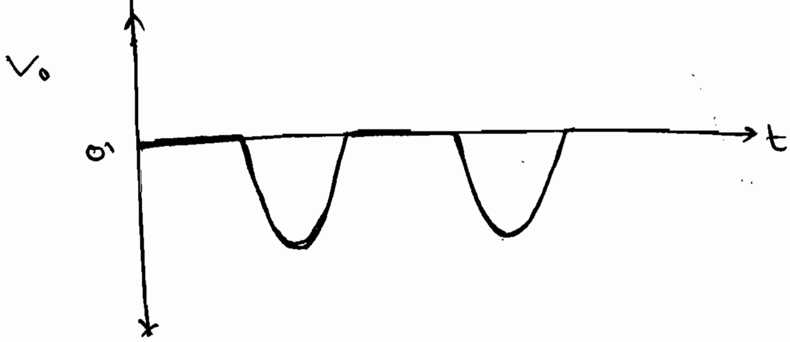
$\therefore V_{in}$ range: -5 to $+5$

V_x range: -5 to $+5$.

V_o range: -5 to 0.

F..





F.B $\quad I > 0$

$\therefore I = \frac{V_{in} - 0}{R}$

$I = \frac{V_{in}}{R}, > 0$

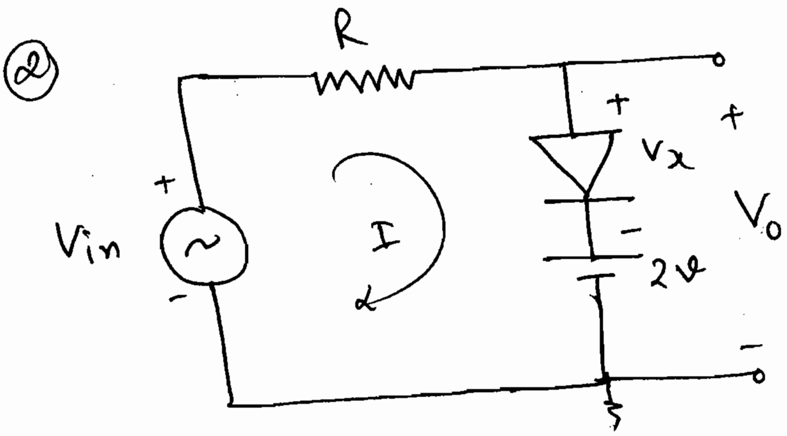
$\therefore \boxed{V_{in} > 0}$ F.B.

$V_{in} \leq 0$. R.B.

$\therefore V_o = V_{in}, \quad V_{in} \leq 0$

$V_o = 0, \quad V_{in} > 0$

(2)



$\therefore$ ~~Vin~~

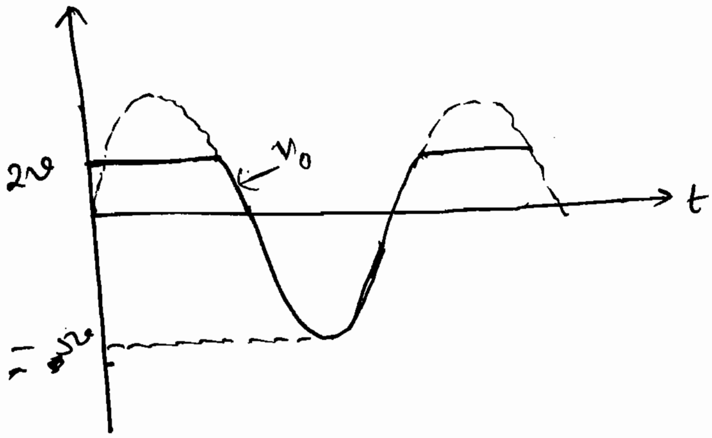
$I = \frac{V_{in} - 2}{R} . > 0$

$\therefore \boxed{V_{in} > 2\,V} \to$ F.B $\to V_o = 2$

R.B. $\boxed{V_{in} \leq 2V} \to V_o = V_{in}$.

$V_o = V_{in} - 2$

$V_o = -5 - ?$



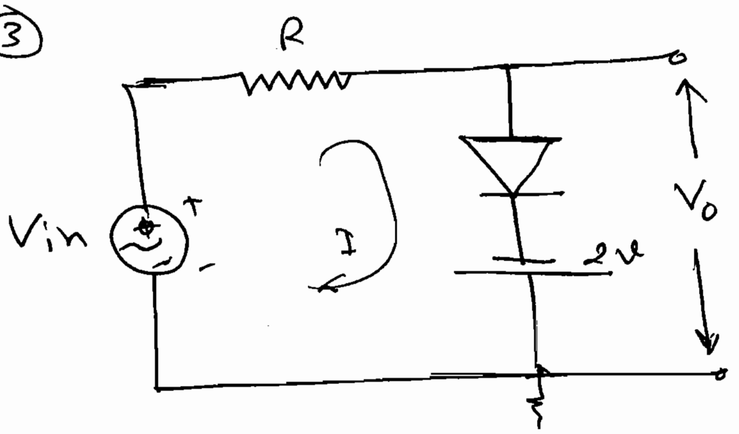
$V_{in} > 2V$
$\Downarrow$
F.B.
$V_o = 2V$.

$\to$ F-B. (S.C)

$V_{in} < 2V$.
$\Downarrow$
R.B
$V_o = V_{in}$

$\to$ R.B (O.C).

(3)



$$I = \frac{V_{in}+2}{R}$$

for F.B. $I > 0$

$$\therefore \frac{V_{in}+2}{R} > 0$$

$$\boxed{V_{in} > -2} \rightarrow \text{F.B.}$$

$\Downarrow$

S.C.

$\Downarrow$

$V_o = -2V$

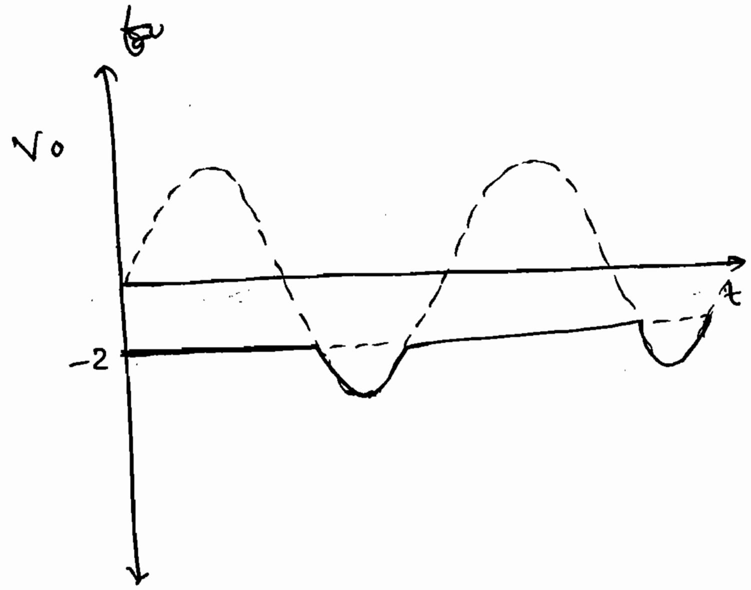
for R.B $I \le 0$.

$$\therefore \boxed{V_{in} \le -2}$$

$\Downarrow$

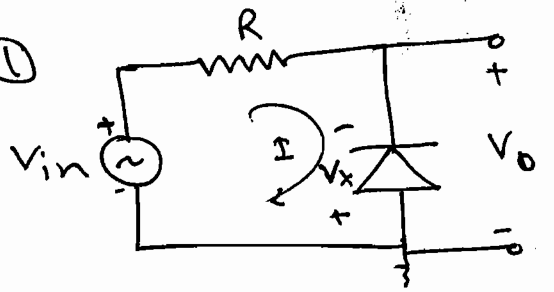
O.C.

$V_o = V_{in}$.



* Sketch v_o:

(1)



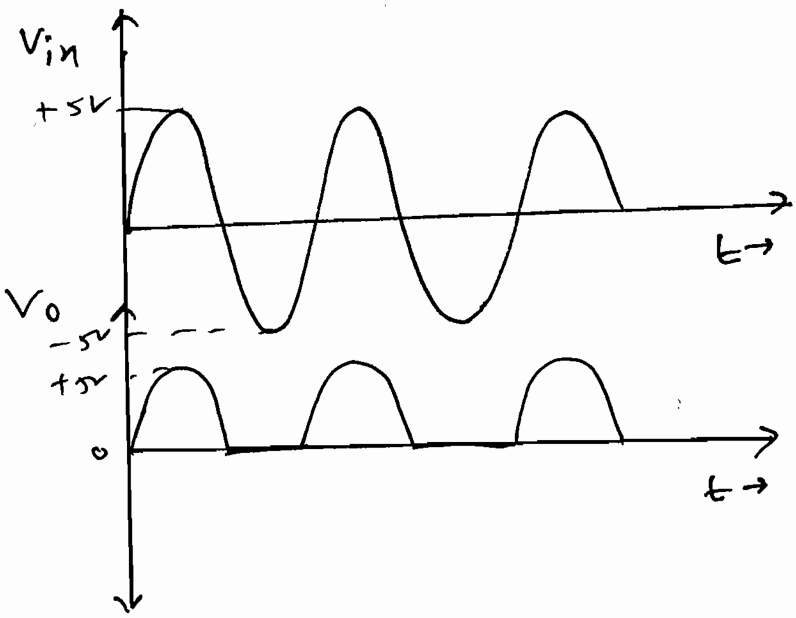
$V_{in} + V_x = 0$

$\therefore V_x = -V_{in}$

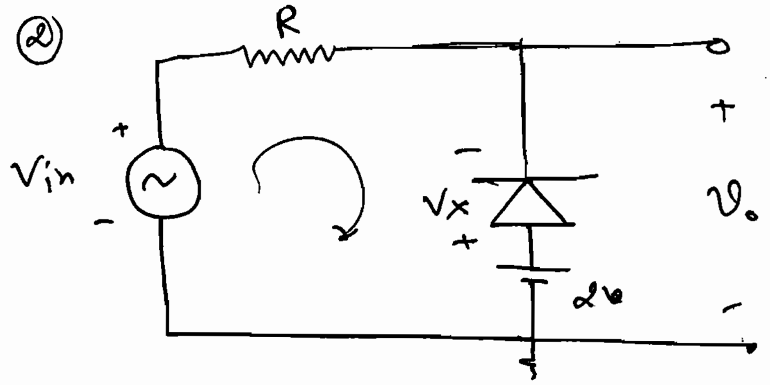
V_{in} range: -5 to $+5$

V_x range: $+5$ to -5.

V_o range: ~~0 to +5~~. 5 to 0.



(2)



$V_{in} + V_x - 2V = 0$

$\therefore V_x = 2 - V_{in}.$

$\therefore V_{in}$ range: -5 to $5V$

V_x range: 7 to $-3V$

V_o range: 7 to $0V$.

$V_x > 0 \rightarrow$ F.B.

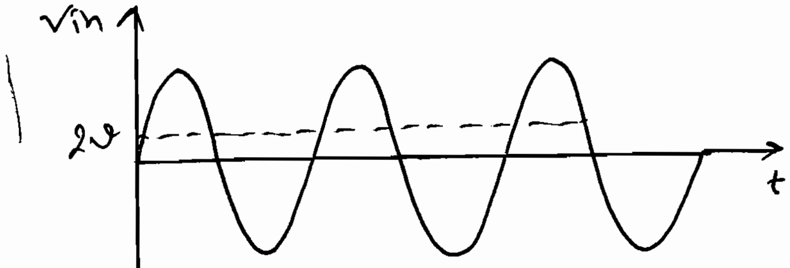
$2 - V_{in} > 0$

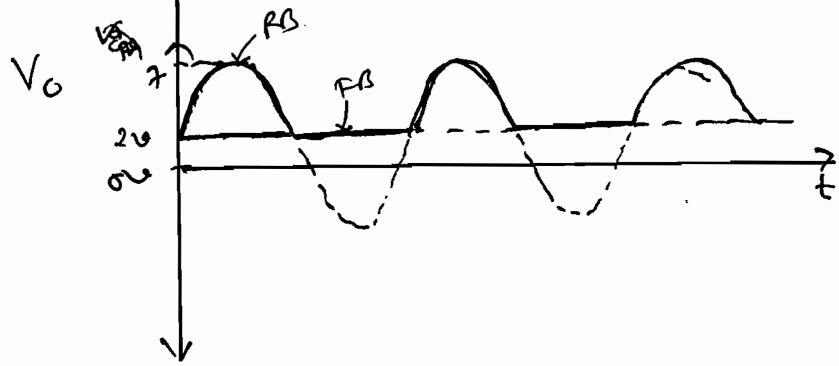
$\boxed{V_{in} < 2V}$

$V_o = 2V.$

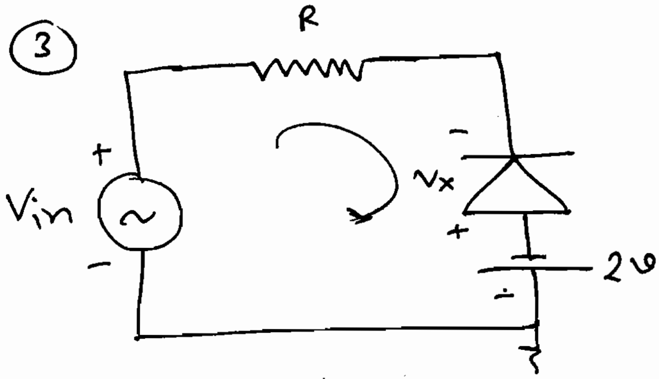
$V_{in} \geq 2V \rightarrow$ RB

$V_o = V_{in}.$





(3)



$V_{in} + V_x + 2V = 0$

$\therefore V_x = -2 - V_{in}.$

V_{in} range: -5 to $+5$.

V_x range: $+3$ to $-7V$

V_o range: $+3$ to $0V$.

$V_x > 0 \rightarrow$ F.B.

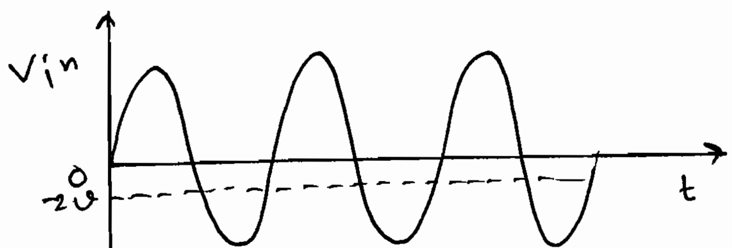
$-2 - V_{in} > 0$

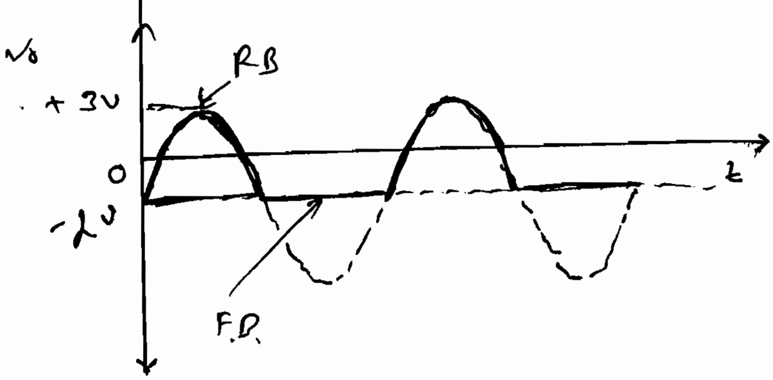
$\boxed{V_{in} < -2V} \rightarrow$ F.B

$\boxed{V_o = -2V}$

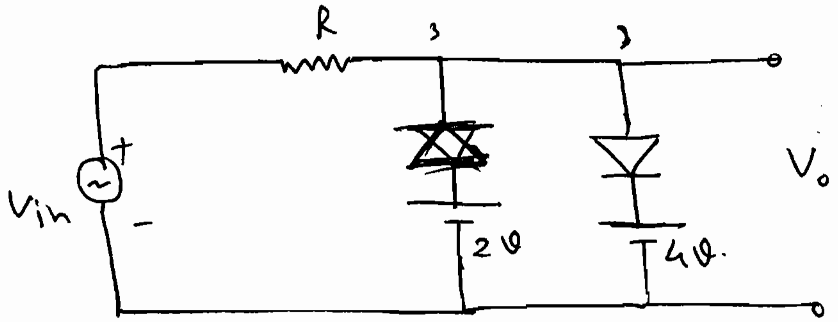
$V_{in} \geq -2V \rightarrow$ R.B.

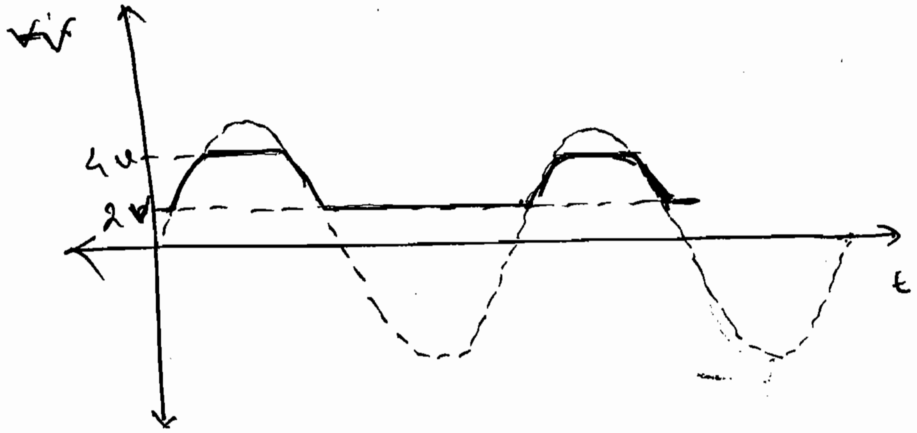
$V_o = V_{in}$



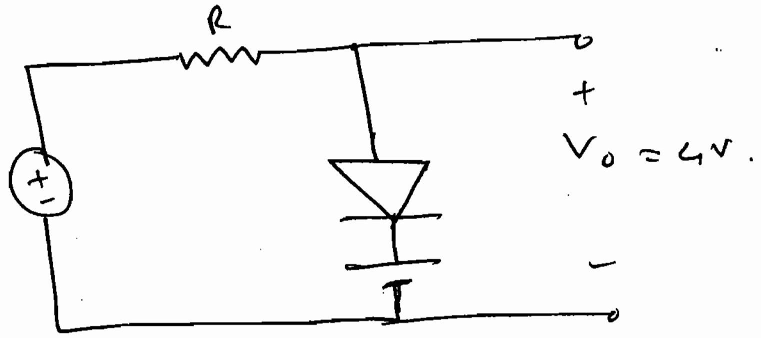


* Design a double bias clipper / slicer

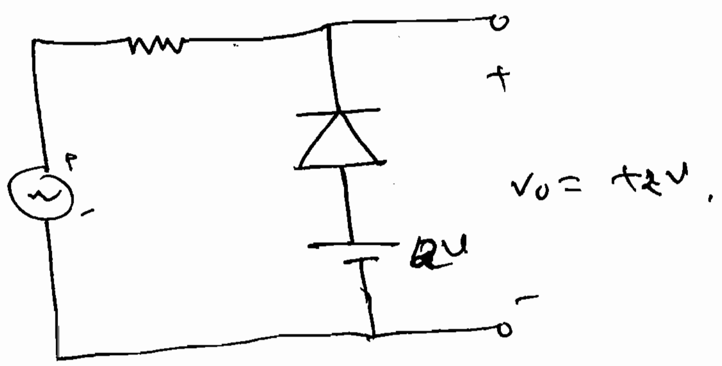




① case-1: Vin > 4 → Vo = +4V.



② case-2 Vin < 2 → Vo = +2V.



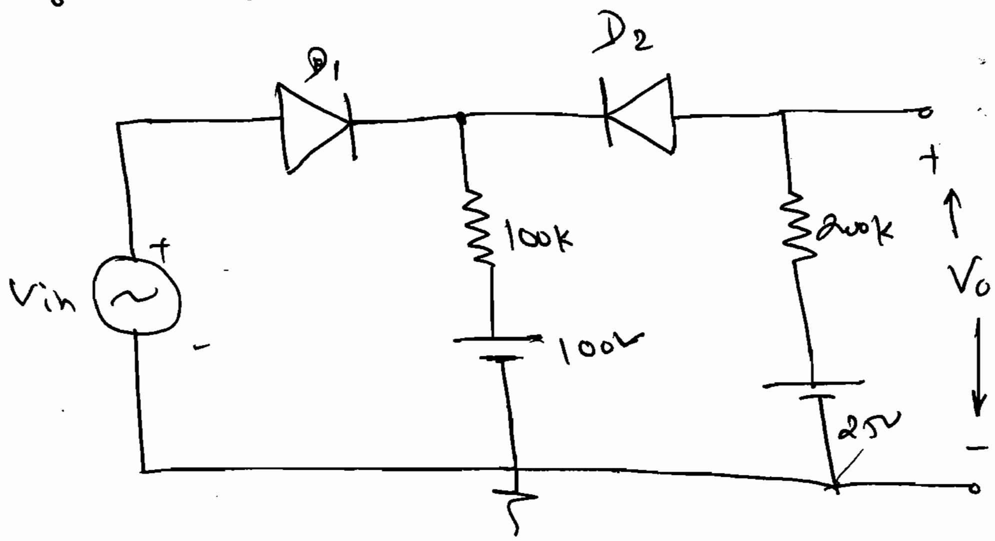
Case-3 2 ≤ Vin ≤ 3.

Both RB

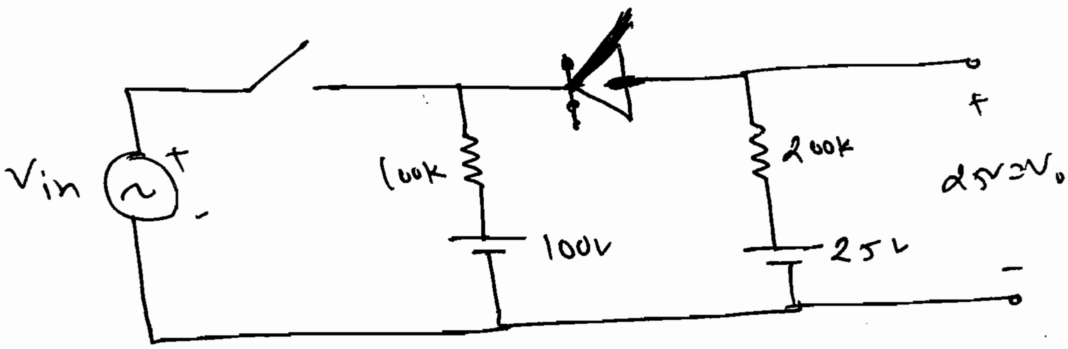
Vo = Vin.

* Sketch the Transfer Characteristics if i/p varies from 0 to 150 V.

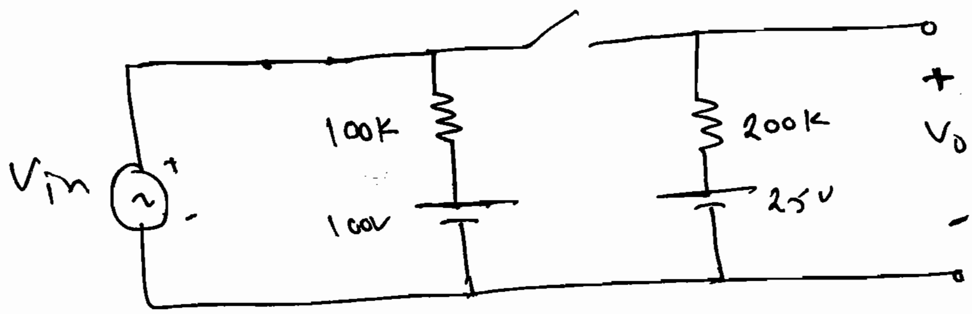
→

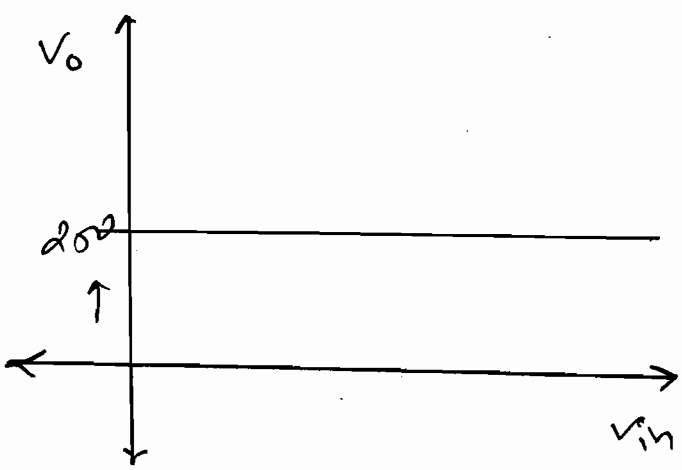


→ Case: (1) $V_{in} = 0V$, so D_1 & D_2 off.



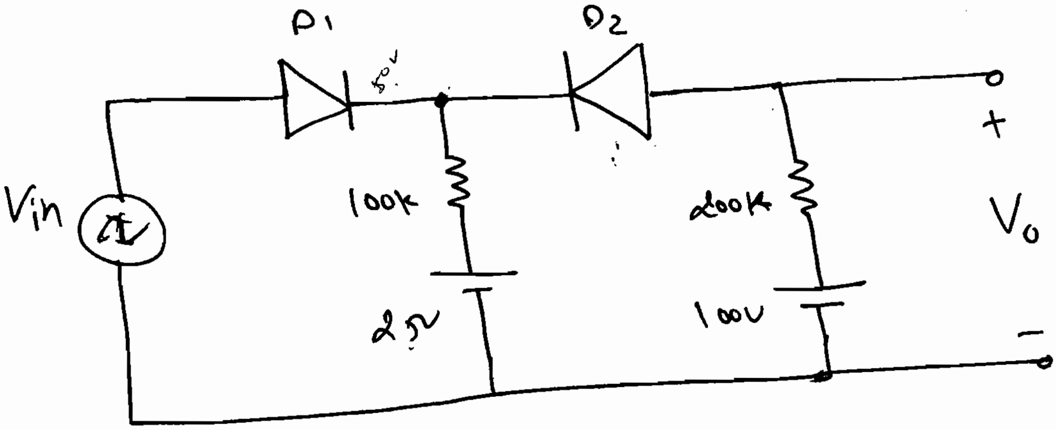
Case- (2) $V_{in} \geq 100V$



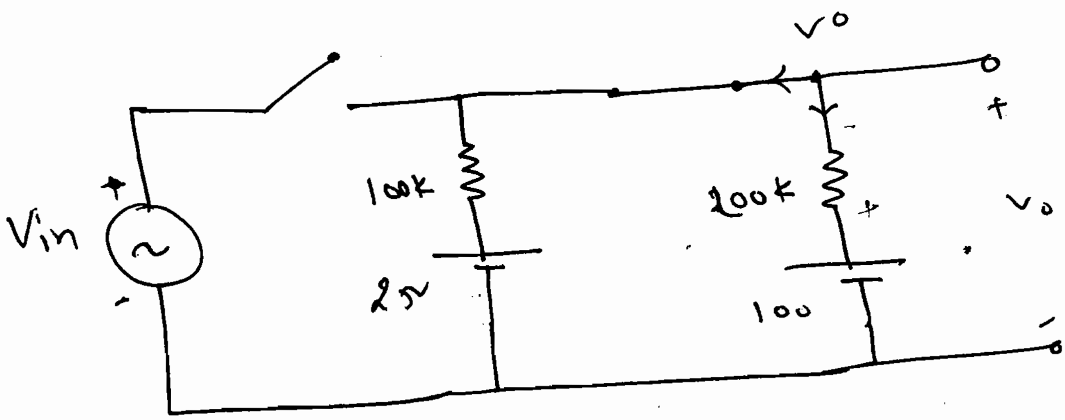


Transfer Characteristic.

* Sketch transfer Char.



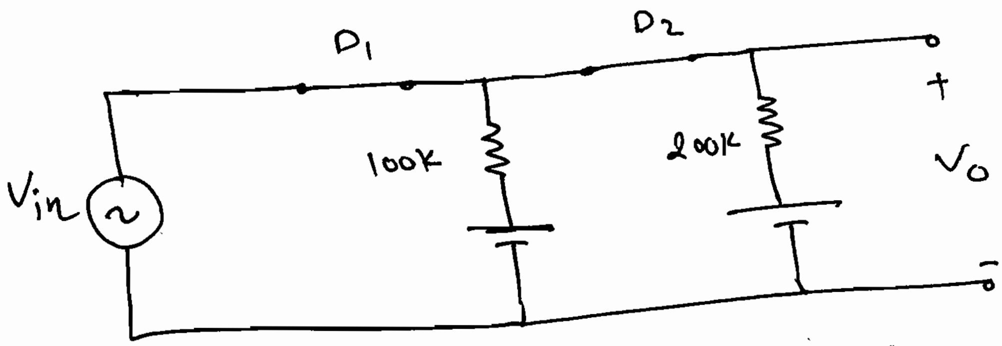
→ Case (i): $V_{in} = 0$, $D_1 = $ off, $D_2 = $ ON.



KCL, $$\frac{V_o - 25}{100} + \frac{V_o - 100}{200} = 0$$

$\therefore \boxed{V_o = 50\,V}$

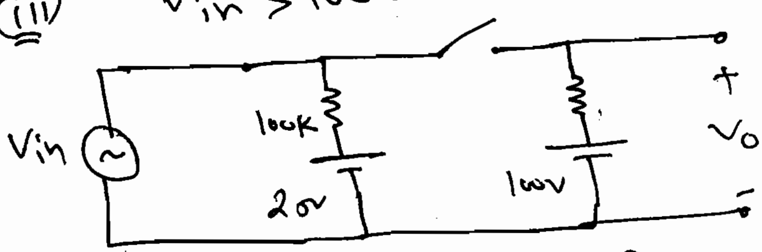
→ Case-(ii) $100V \geq V_{in} > 50V$. $D_1 = $ ON, $D_2 = $ ON.



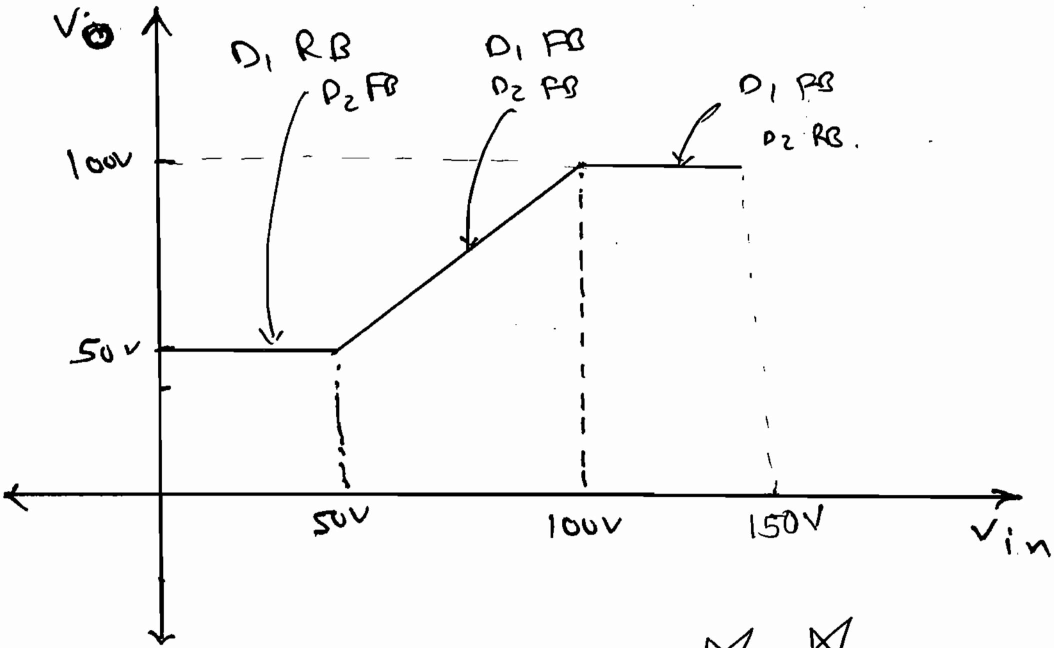
$V_o = V_{in}$.

$V_o = V_{in}$.

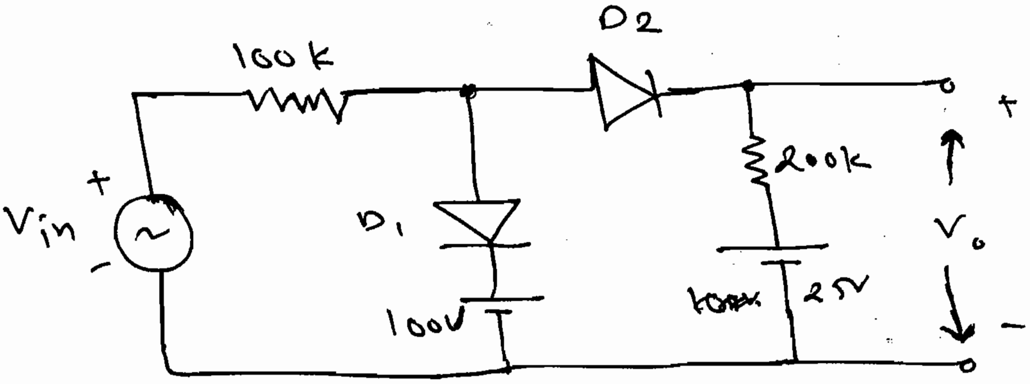
→ Case (iii) $V_{in} > 100V$.



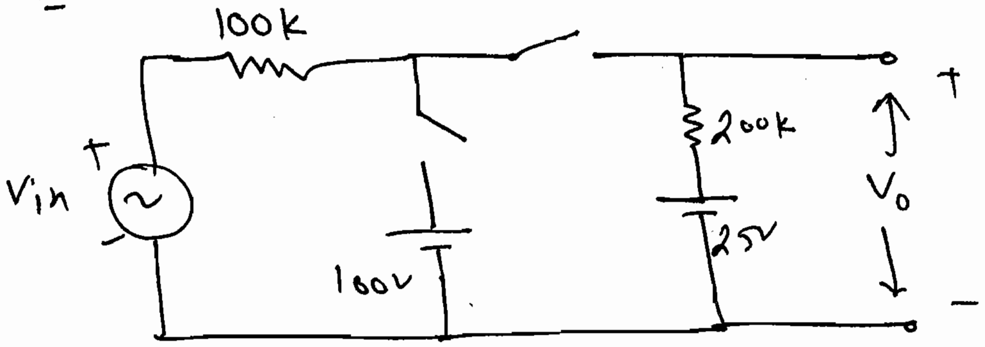
$V_o = 100V$.



* Sketch transfer char:

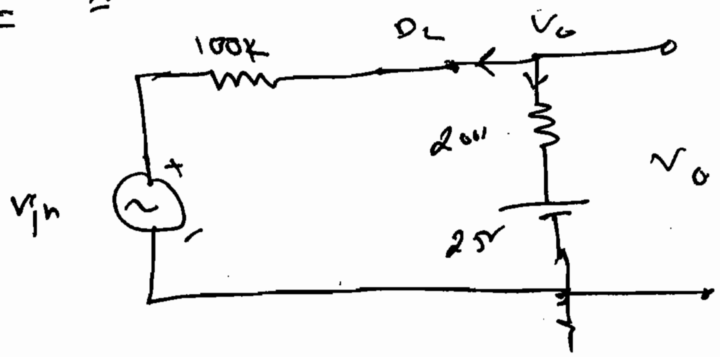


Case-(i) $V_{in} = 0$. , $D_1 = OFF$, $D_1 = OFF$



$\boxed{V_o = 25V}$

Case-(ii) $V_{in} \geq 25V$. $D_1 = off$, $D_2 = ON$.



$$\therefore \quad \frac{V_0 - V_{in}}{100} + \frac{V_0 - 25}{200} = 0.$$

$$\therefore \quad 2V_0 - 2V_{in} + V_0 - 25 = 0.$$

$$\therefore \quad 3V_0 = 2V_{in} + 25.$$

$$\therefore \quad V_0 = \frac{2}{3} V_{in} + \frac{25}{3}.$$

Now, max value of $V_0 = 100\,V$.

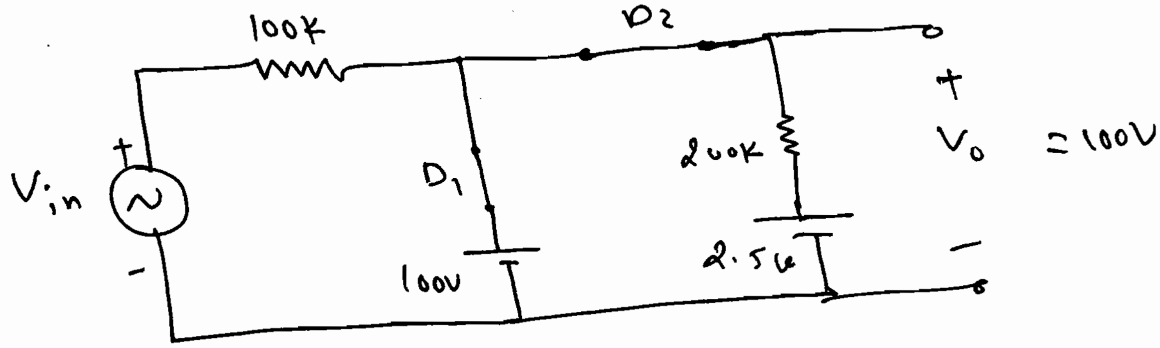
$$\therefore \quad 100 = \frac{2}{3} V_{in} + \frac{25}{3}.$$

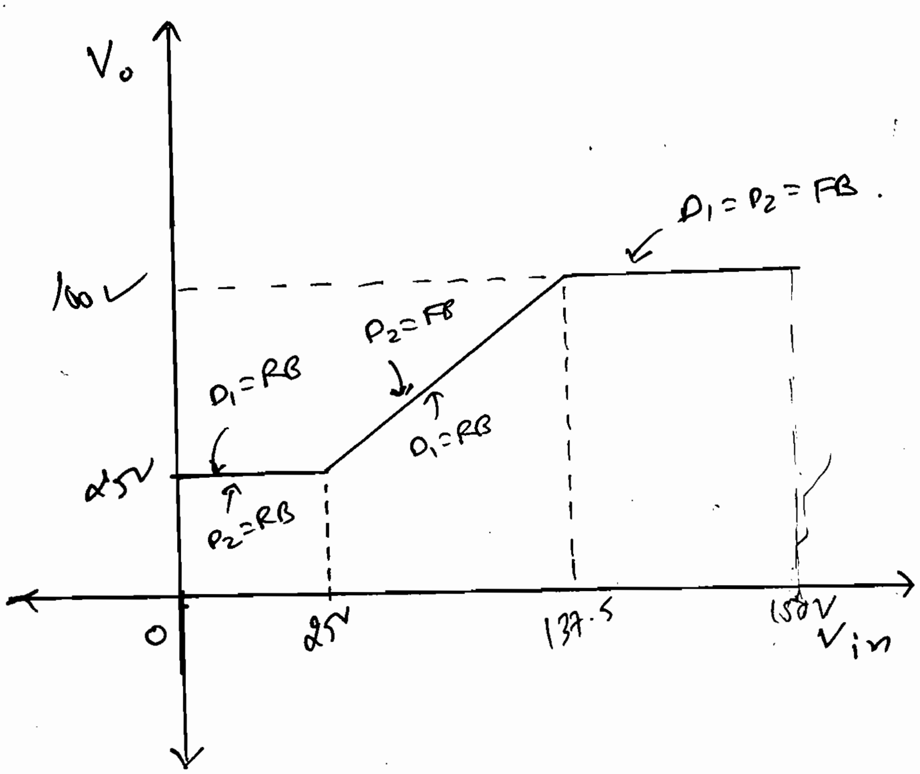
$$\therefore \quad \frac{300 - 25}{2} = V_{in}$$

$$\therefore \quad V_{in} = 137.5\,V. \Rightarrow V_0 = 100\,V.$$

Case-(iii)

when $V_{in} > 137.5$. $D_1 = ON$, $D_2 = ON$.



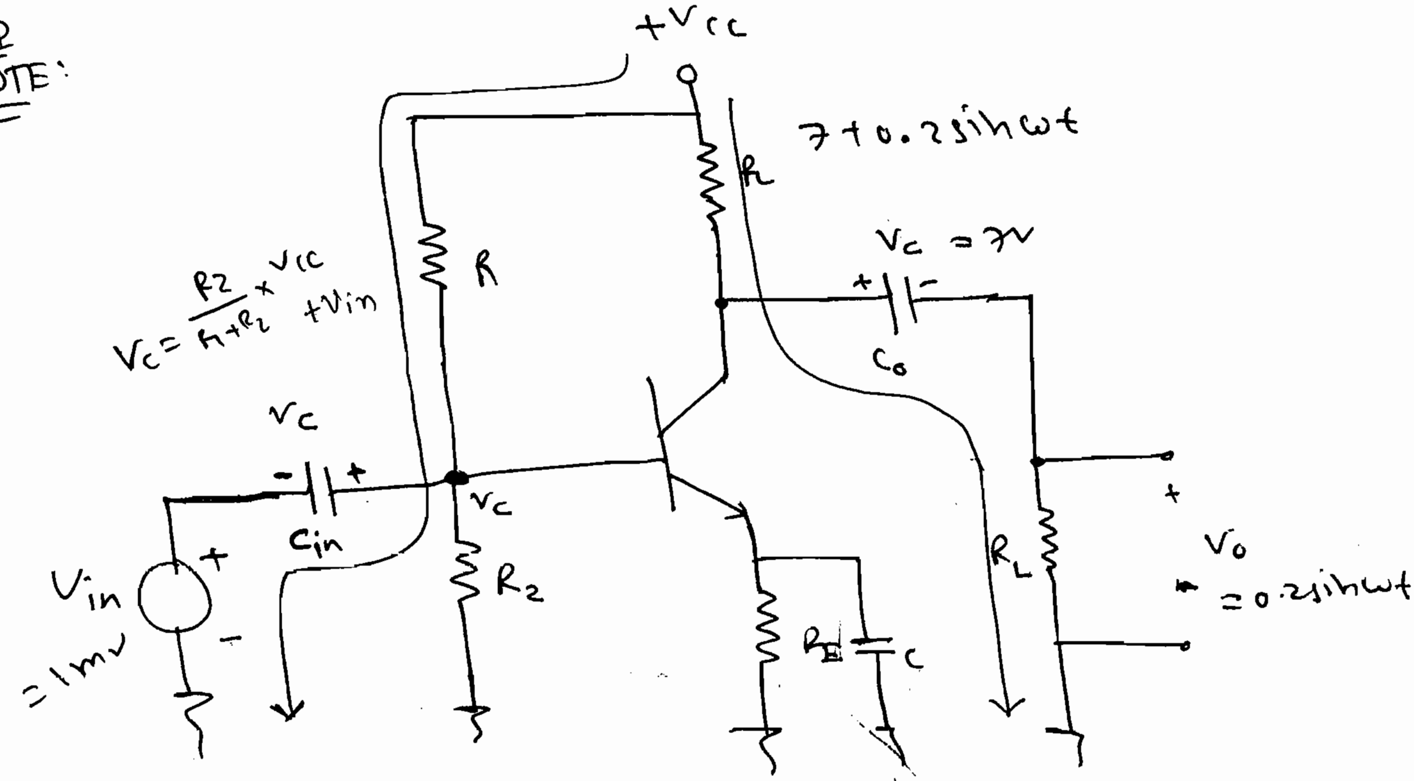


☆ Clamping circuits or Clampers:

→ Clamper is a circuits that Adds DC to the given input wave form.

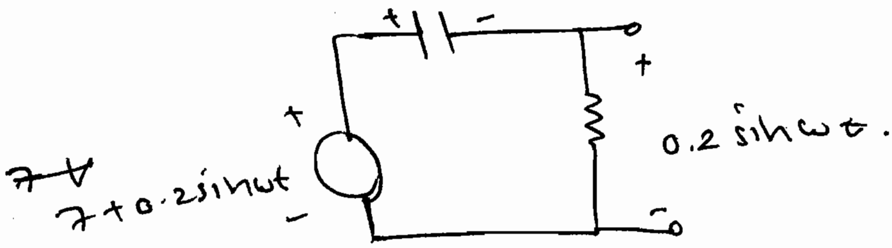
→ Also called DC Restorer.

Imp NOTE:



Clampper

→ ① for V_o.

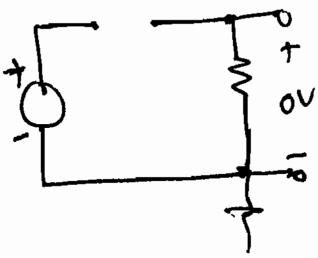


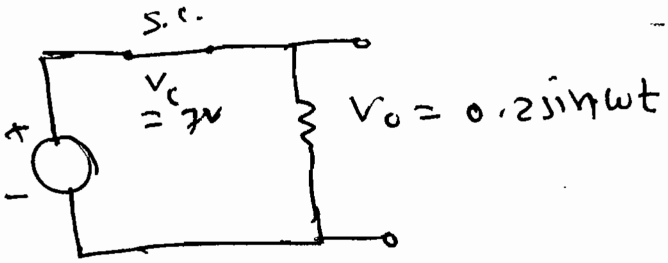
$Z = \left|\frac{1}{\omega C}\right| \Omega$

(D.C). $\omega = 0 \Rightarrow Z = \infty$ O.C.

(A.C) $\omega = \infty \Rightarrow Z = 0$ S.C.

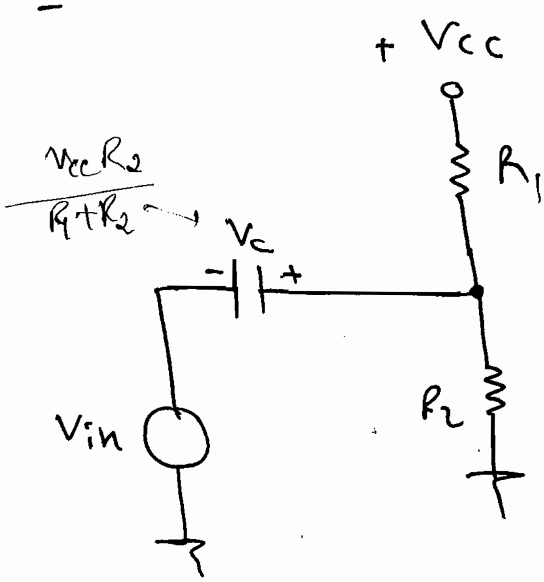
DC	AC
$\omega = 0$	$\omega = \infty$
$Z = \infty$	$Z = 0$
O.C.	S.C.





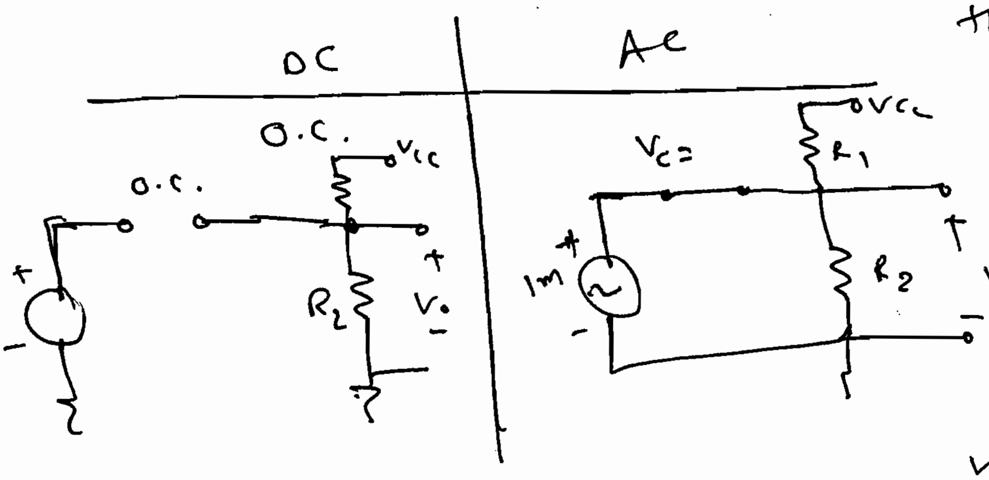
→ So, at o/p capacitor is used to block DC component and allow AC component.

② <u>At</u> <u>i/p</u>:



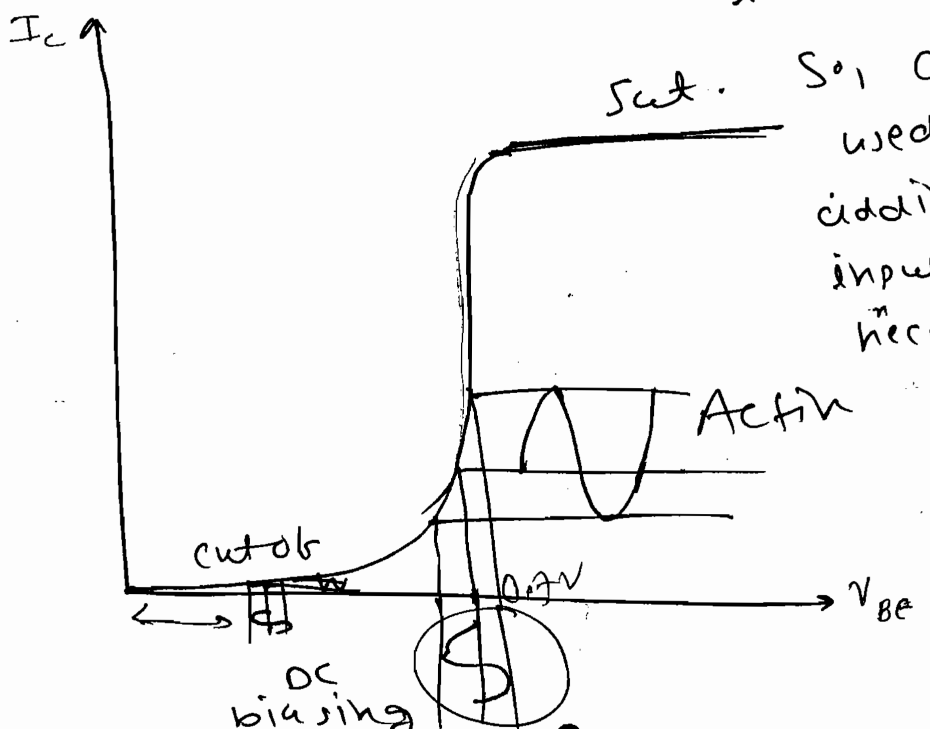
* If we don't use capacitor C_i then very small input voltage available and therefore the device is in cut off region.

→ Now, because of capacitor it store the DC voltage and this DC voltage are used Add to the input so that DC biasing point shift from small value to large value so that the device will come into active region.



$$\therefore V_o = \frac{R_2}{R_1+R_2} \times V_{cc}$$

<u>Biasing</u>: Adding some DC.



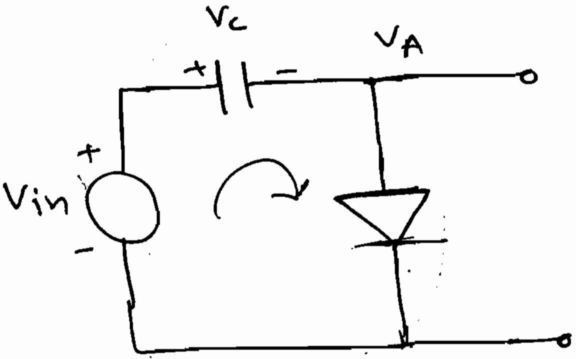
So, capacitor is used for the adding dc to input and hence act as clamper.

☆ Two simple steps to draw the clamped output:

(i) Find the capacitor voltage V_c in its steady state.

(ii) Replace diode with open switch and draw the output waveform.

Ex-1

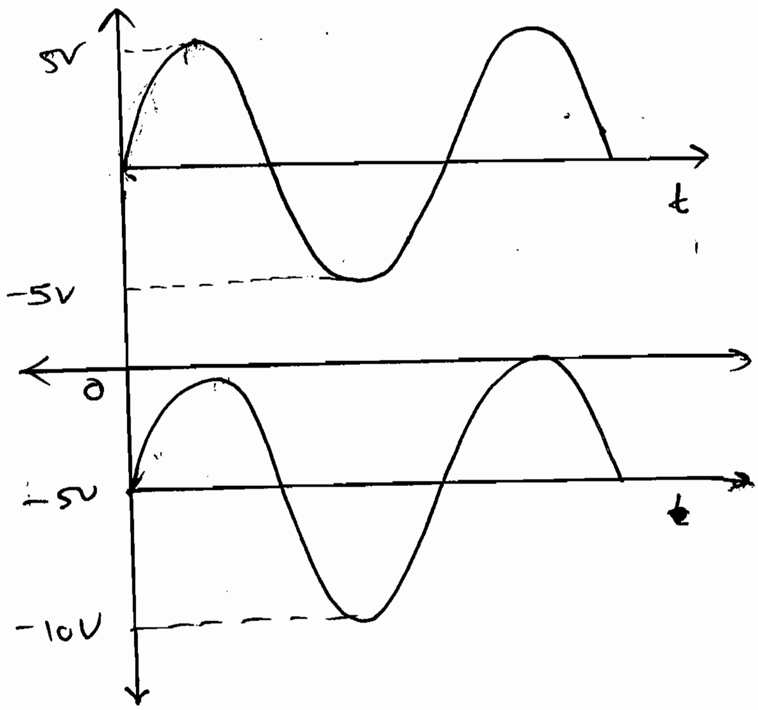


$V_A = V_{in} - V_c$

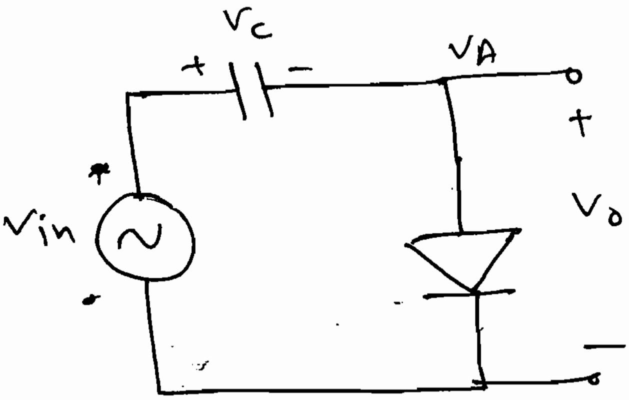
$V_A = V_{in} - 5$ $\quad V_c = +5V.$

V_{in} range: -5 to $+5$

V_A range: -10 to $0V$. (neg).



Ex-2

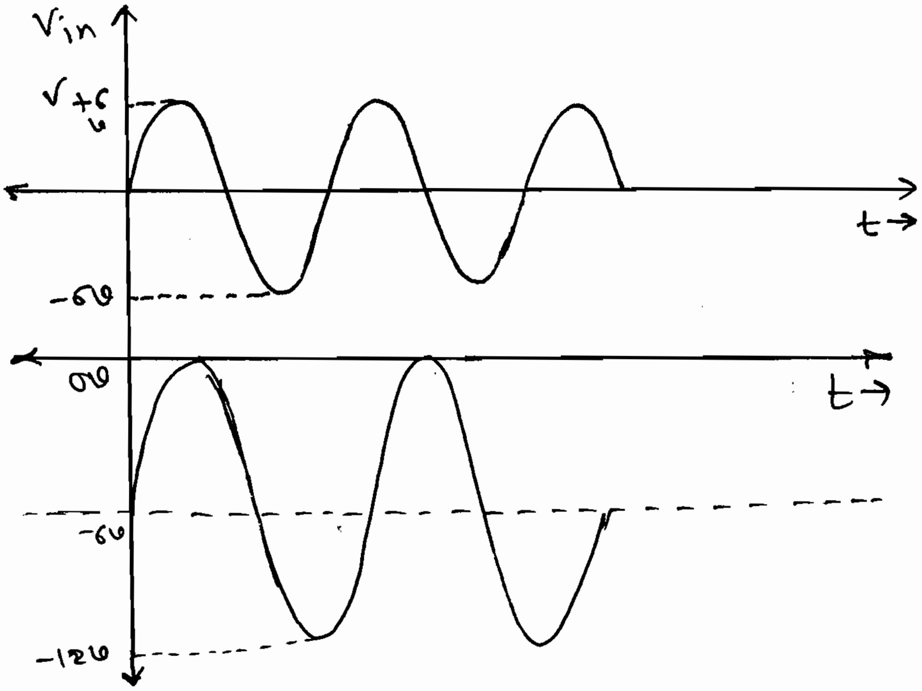


$V_c = 6V$

$V_A = V_{in} - 6$,

V_{in} range: -6 to $+6V$.

$\therefore V_o$ range: -12 to $0V$.



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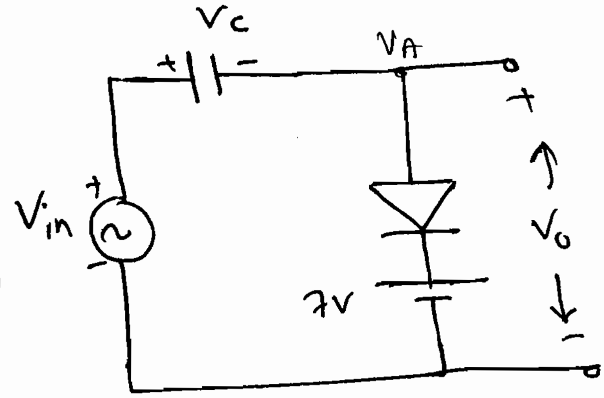


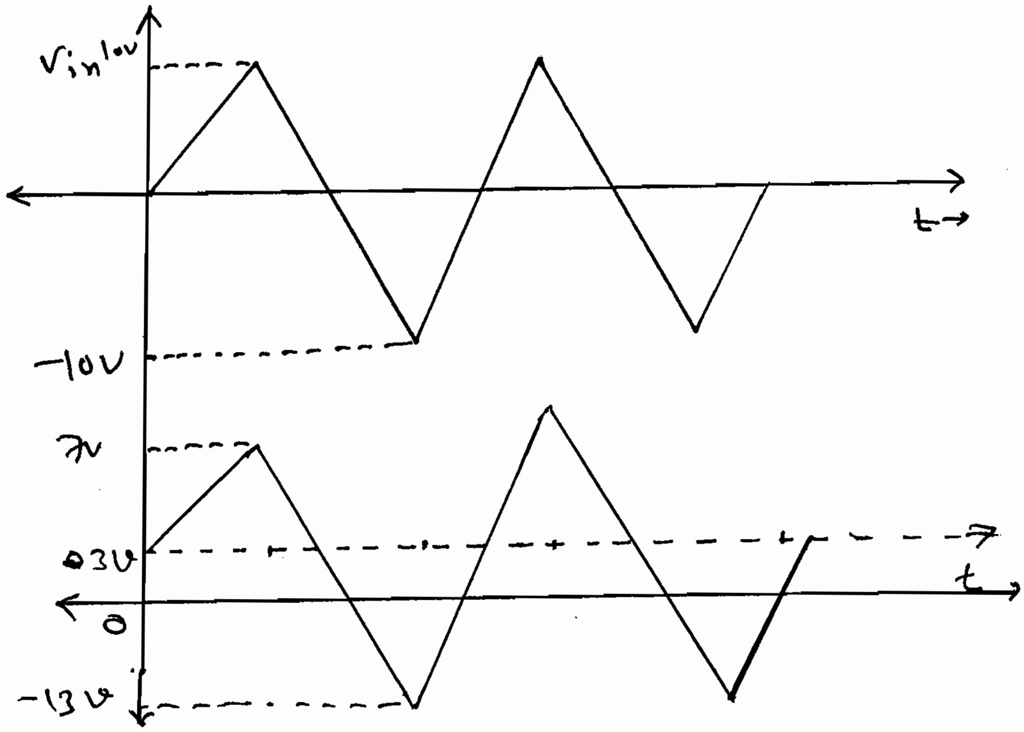
$10 - V_c - 7 = 0$

$\boxed{V_c = 3V}$

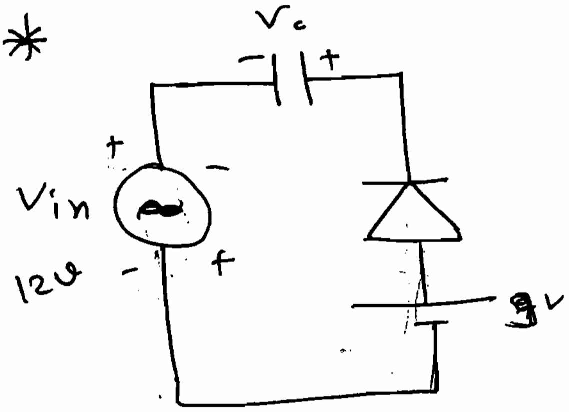
V_{in} Reng: -5 ~~to~~ $+5$.

$V_o = V_{in} - 3$ v.

V_o range: 7 to -13v.



*



$v_{in} + v_c - 7 = 0.$

∴ ~~$v_{in}/7$~~

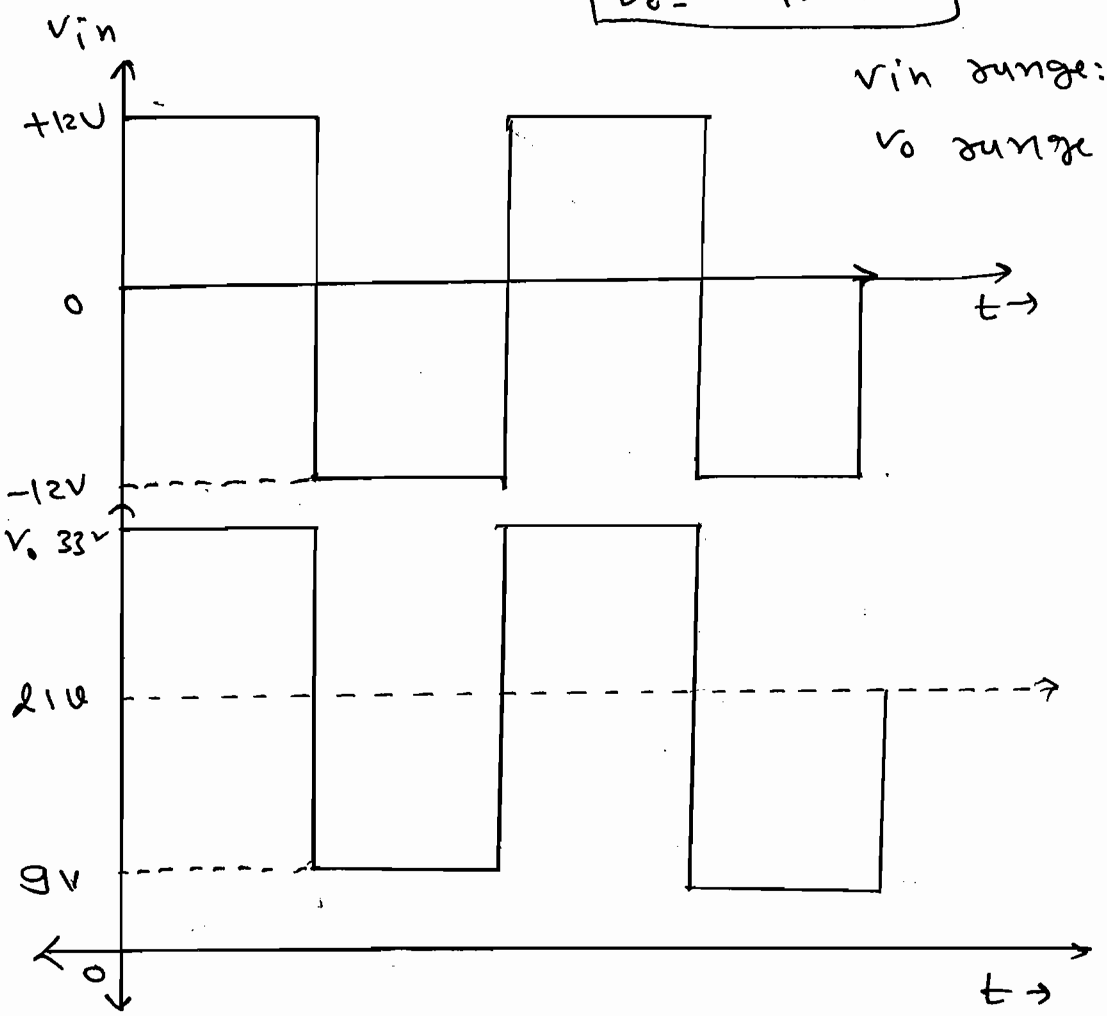
∴ ~~$+12$~~

$-12 + v_c - 9 = 0$

$\boxed{V_c = 21V}$

$v_o = v_{in} + v_c$

$\boxed{v_o = v_{in} + 21.}$



v_{in} range: -12 to 12

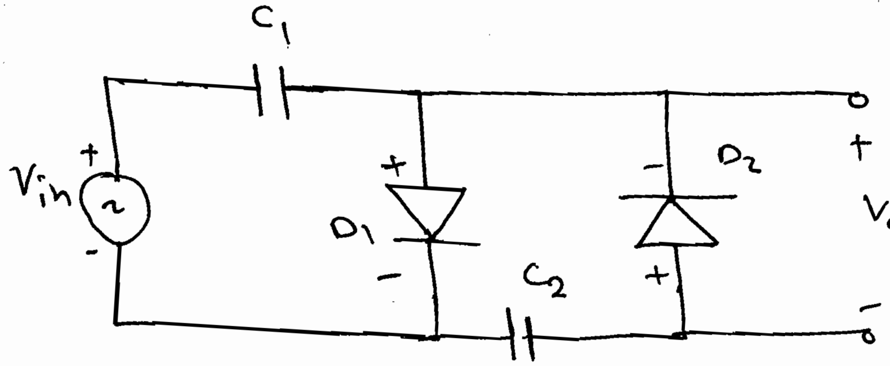
v_o range: 9 to 33.

☆ Voltage Mutiplier:

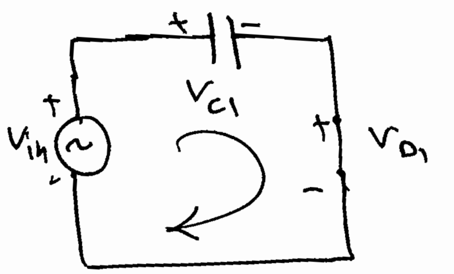
→ $V_{in} = V_m \sin \omega t$ (AC)

$V_o = n V_m$ (DC) $\quad n = 2, 3, 4, \ldots$

* Doubler:



⇒ During +ve cycle



$\therefore V_{in} - V_{C1} = 0\,V$

$\therefore \boxed{V_{C1} = 6V.}$

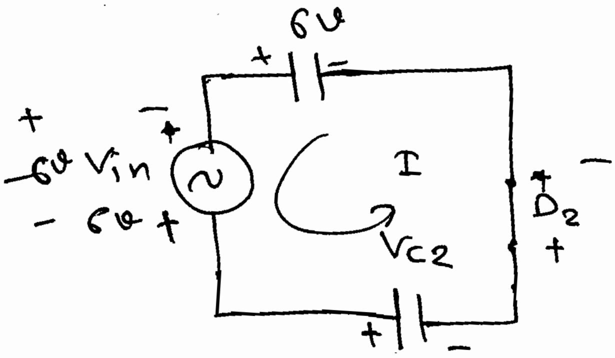
$\therefore V_{in} - 6V - V_{D1} = 0.$ [when V_{D1} is R.B]

$\therefore \boxed{V_{D1} = V_{in} - 6 \; V}$

V_{in} range: -6 to $+6$

V_{D1} range: -12 to $0\,V$

⇒ During -ve cycle.



$\therefore V_{in} - V_{C2} + 6 = 0$

$V_{C2} = V_{in} + 6.$

$\therefore V_{C2} = 6 + 6 = 12V.$

$\boxed{V_{C2} = 12V}$

$\therefore V_{in} - 6 + V_{D2} + V_{C2} = 0$

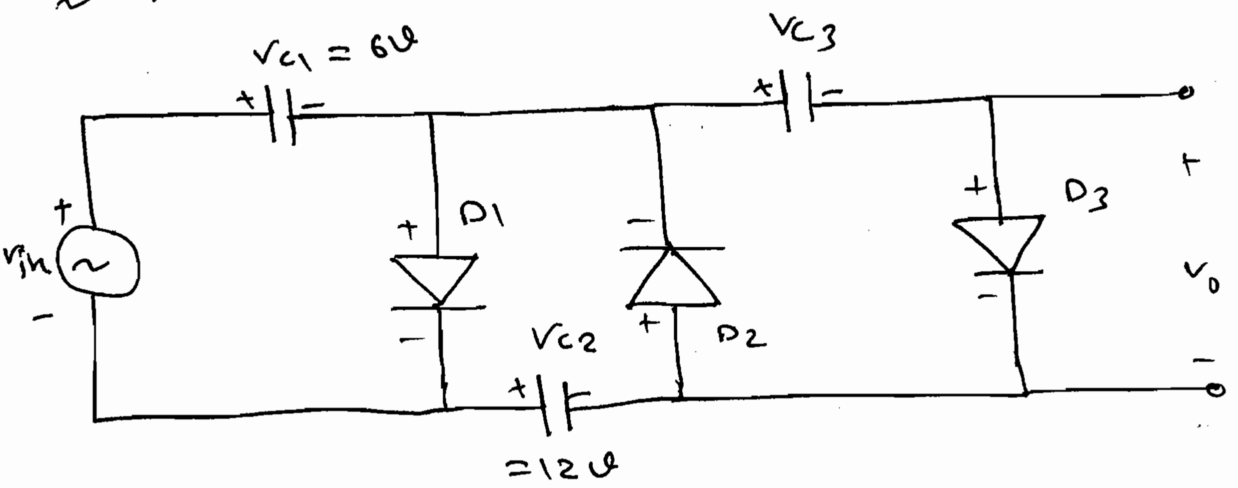
$\therefore V_{in} - 6 + V_{D2} + 12 = 0$

$\therefore \boxed{V_{D2} = -(V_{in} + 6)\,V}$

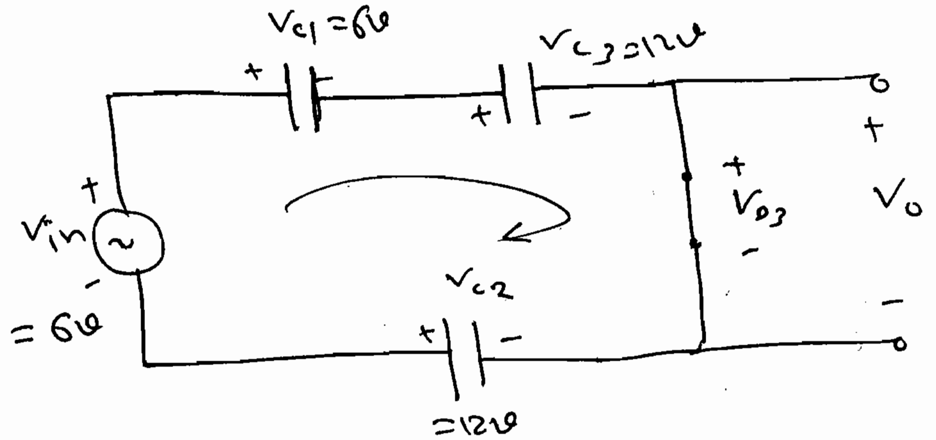
V_{in} range: -6 to $+6V$

V_{D2} range: 0 to $-12V$.

* Voltage tripler:



→ Now again in second positive cycle,



$\therefore \quad V_{in} - 6 - V_{c3} + V_{c2} = 0$

$\therefore \quad 6 - 6 - V_{c3} + 12 = 0.$

$\therefore \quad \boxed{V_{c3} = 12V}$

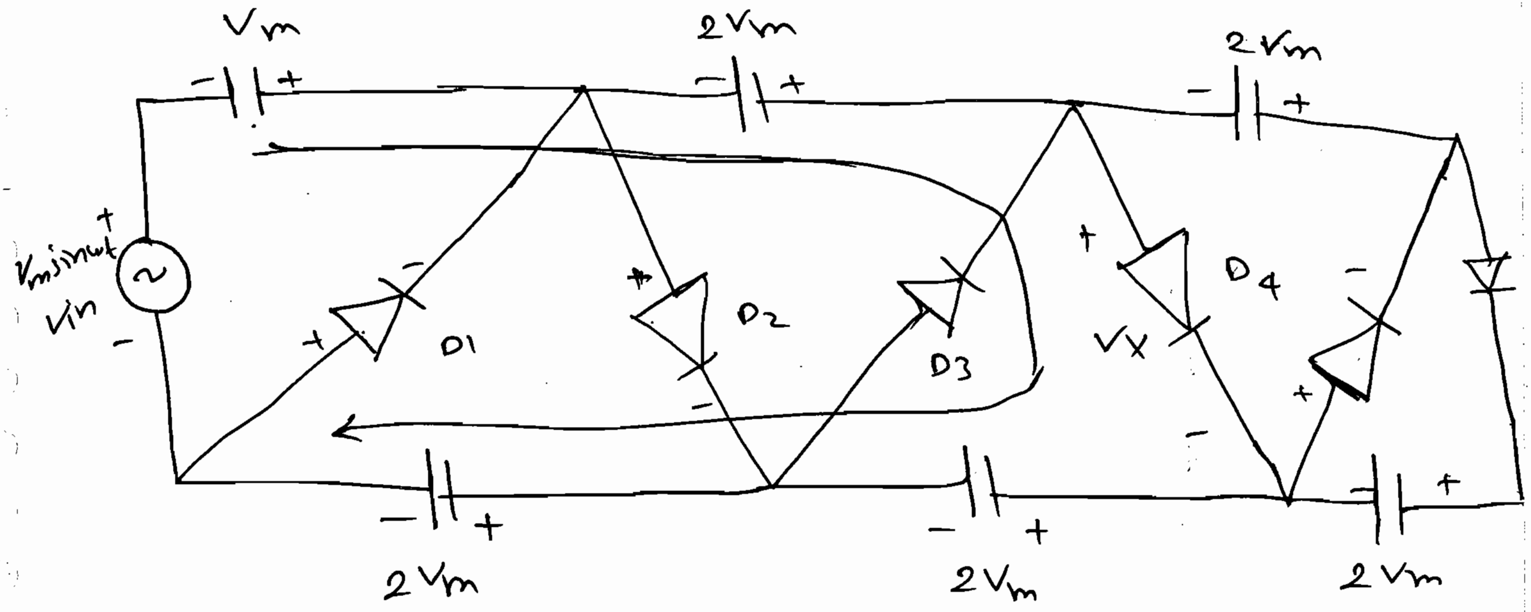
$\therefore \quad V_{in} - V_{c1} - V_{c3} + V_{D3} + V_{c2} = 0.$

$\therefore \quad V_{in} - 6 - 12V + V_{D3} + 12V = 0.$

$\therefore \quad \boxed{V_{D3} = V_{in} - 6V}$

So, Capacitor can charge up to only voltage range of input.

*

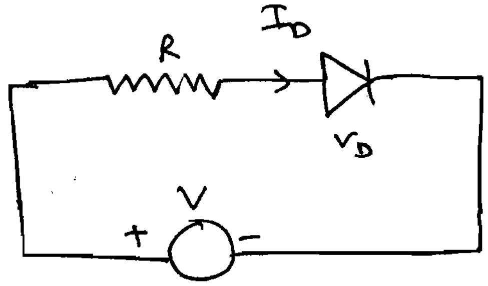


$\therefore \quad V_{in} + V_m + \cancel{2V_m} - V_x - \cancel{2V_m} - 2V_m = 0$

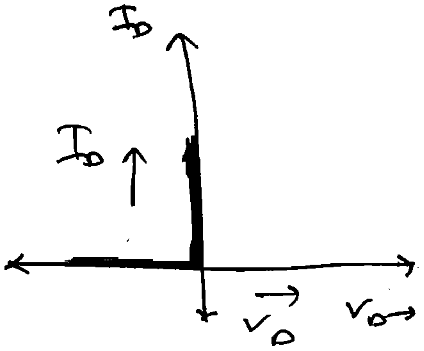
$\therefore \quad \boxed{V_x = V_{in} - V_m.}$

D: 09/07/2013

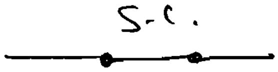
*

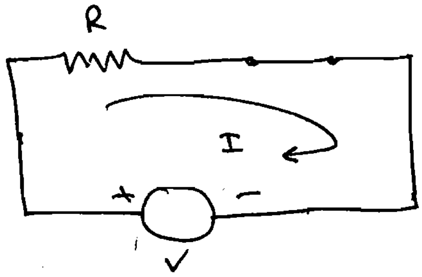


→



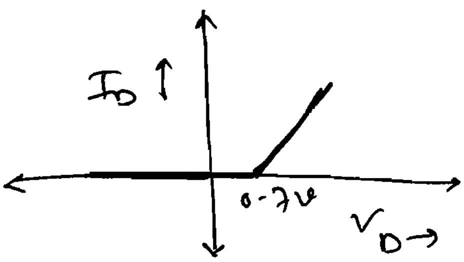
Model

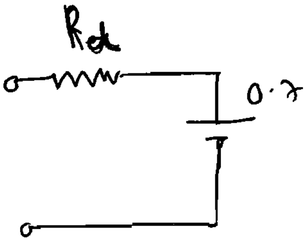


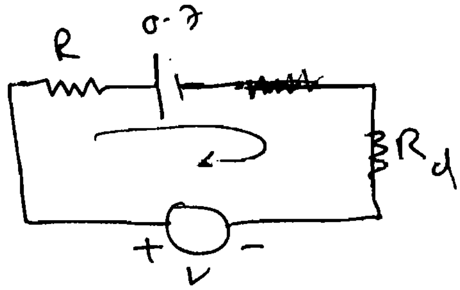


$I = V/R.$

→

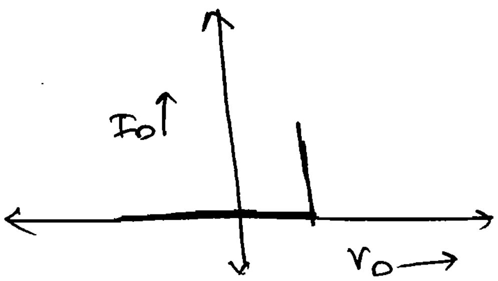


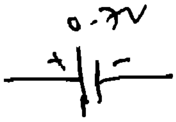




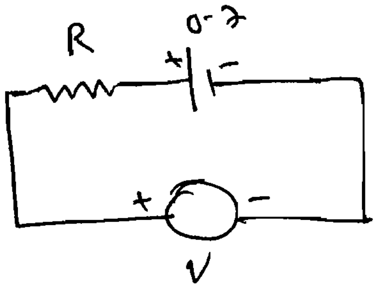
$$I = \frac{V - 0.7}{R + R_d}.$$

→



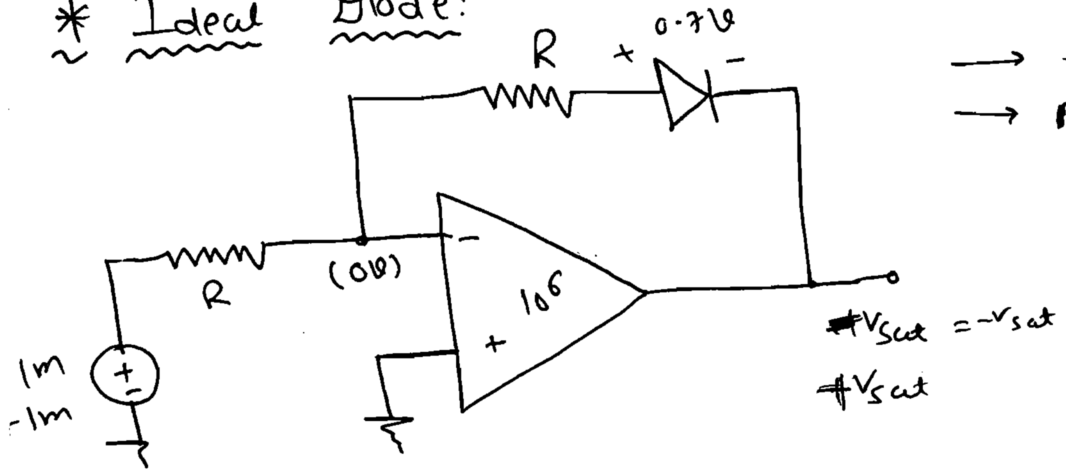


$V_D = 0.7$

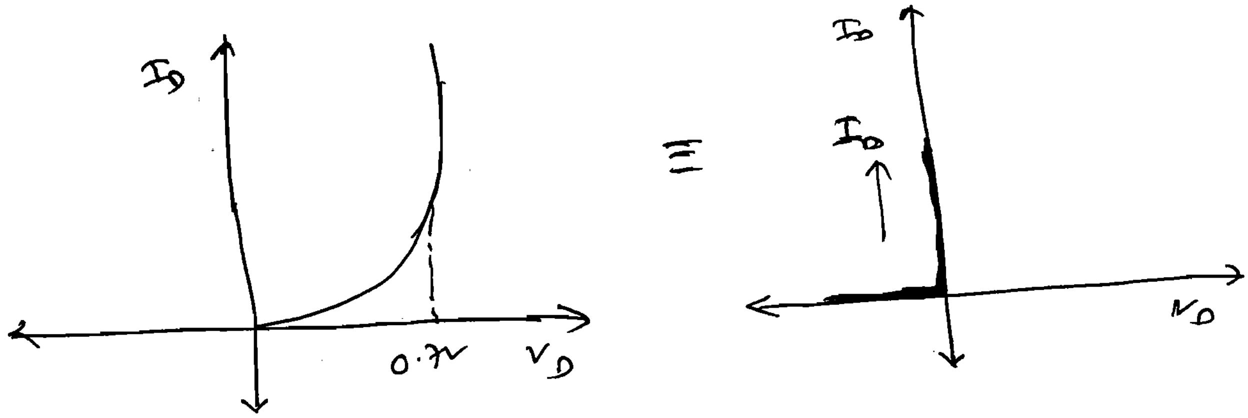


$$I = \frac{V - 0.7}{R}.$$

* Ideal Diode:



→ Super diode
→ precesion diode.



→ When diode is F.B. the OP-Amp is in close loop configuration.

→ But at initial stage input voltage is very small and so diode is off for a very small time. and so op-Amp is is in open loop configuration. so

o/p is $V_o = AV_d$

$\therefore V_o = 10^6 \times (1mv) \approx 1000V$.

But, V_o never exceed $\pm V_{sat}$ so.

$\therefore V_o = -V_{sat}$ ($\because$ inverting amp.).

Now, this $-V_{sat}$ make diode F.B. and op-Amp is now in close loop configuration.

→ so, within a no time. diode will be in F.B. condition i.e. $\frac{0.7}{10^6}$ v required to turn on the diode instead of 0.7 v.

So, for 1 mV, diode will be on and it is look like a ideal diode. as shown in figure.

Note:

→ virtual ground concept apply only when open op-Amp is in its negative close loop negative (feedback) configuration.

→ When the diode is on then apply virtual ground concept.

→ When the diode is off i.e O.C then op-Amp is in open loop op-Amp.

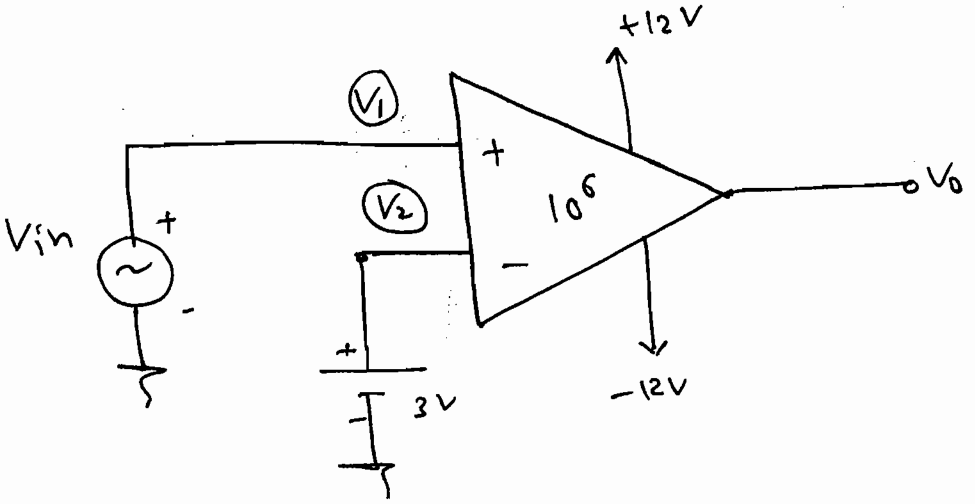
→ Can not apply virtual ground concept in the feedback also.

→ When diode or BJT are driven by op-Amp then there is changing to ideal diode.

→ Diode and BJT can be driven by op-Amp.

→ op-Amp is driver.

* Open loop Configuration: (Comparator).



$\rightarrow \quad V_0 = A\,[V_1 - V_2].$

$\therefore \quad V_0 = A\,[V_{in} - 3].$

Case-(i) when $V_{in} > 3 \Rightarrow V_{in} - 3$ is positive.

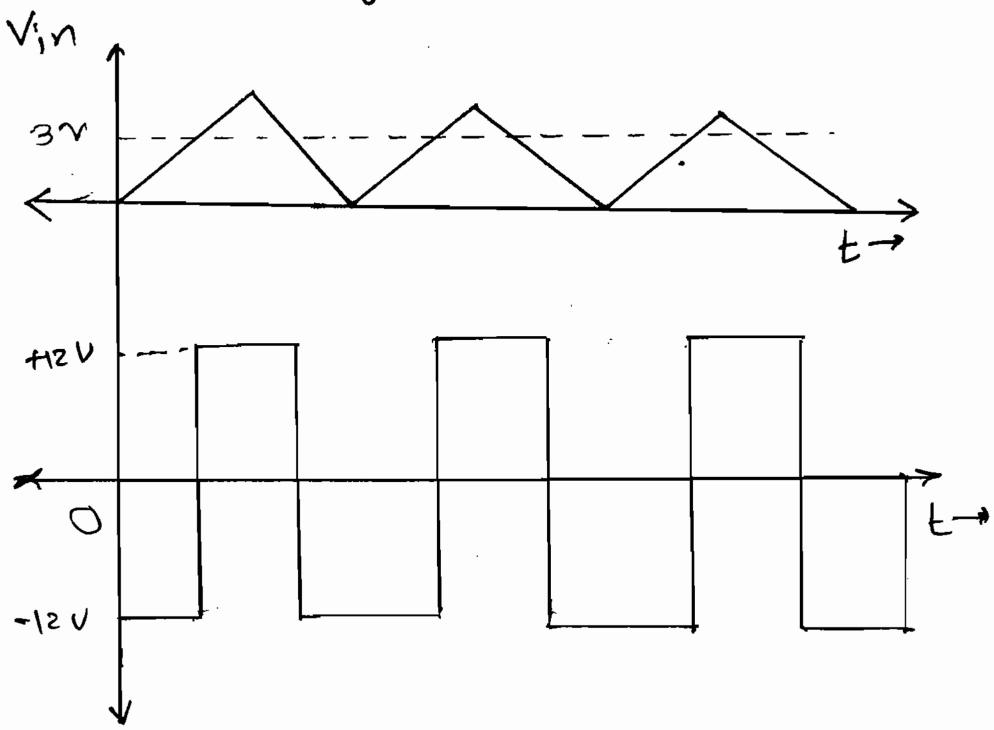
$\rightarrow \quad V_0 = 10^6$ [small pos].

$V_0 = +V_{sat} = +12V.$

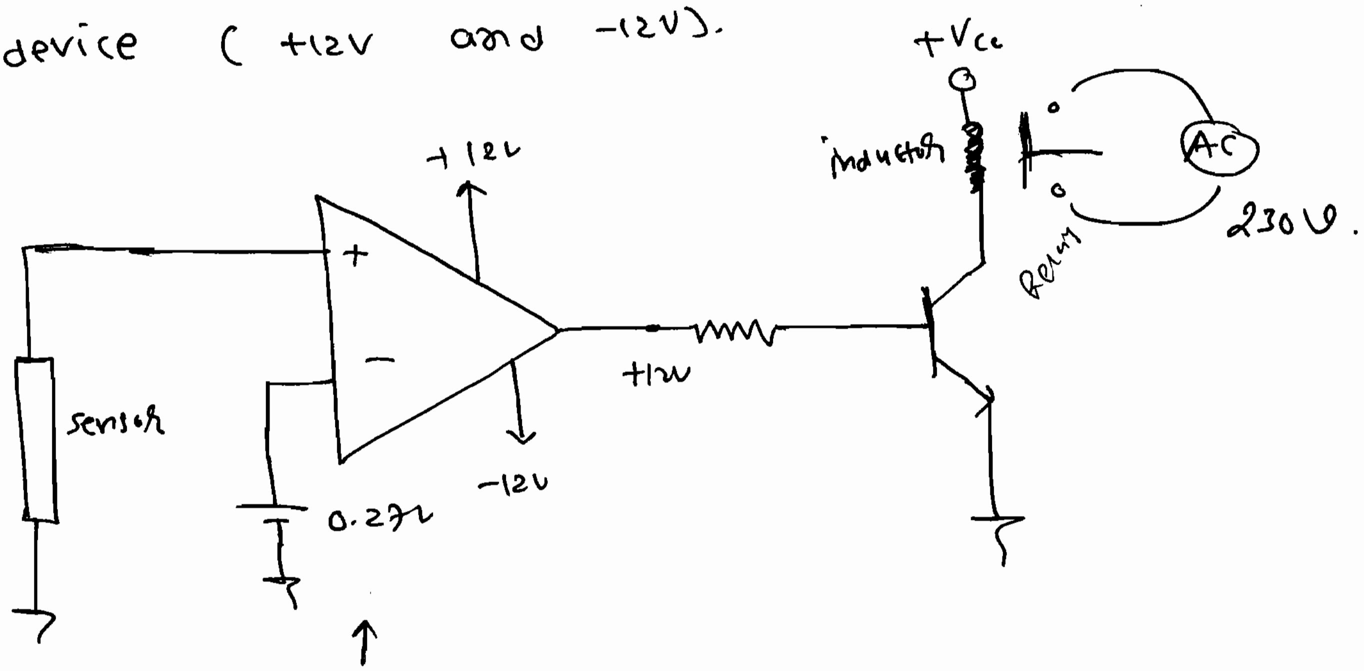
Case-(ii) When $V_{in} < 3 \Rightarrow V_{in} - 3$ is negative

$\rightarrow \quad V_0 = 10^6$ [small neg]

$V_0 = -V_{sat} = -12V.$

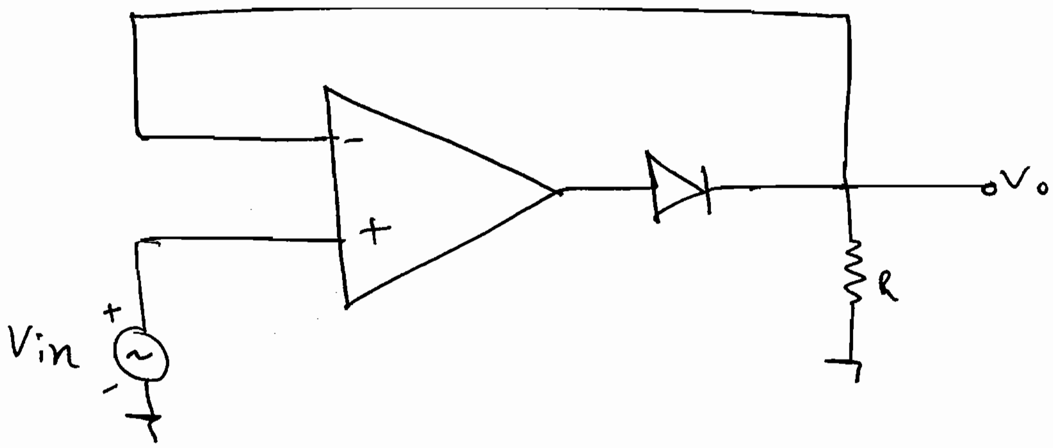


→ it is used for switching purpose for external device (+12V and -12V).

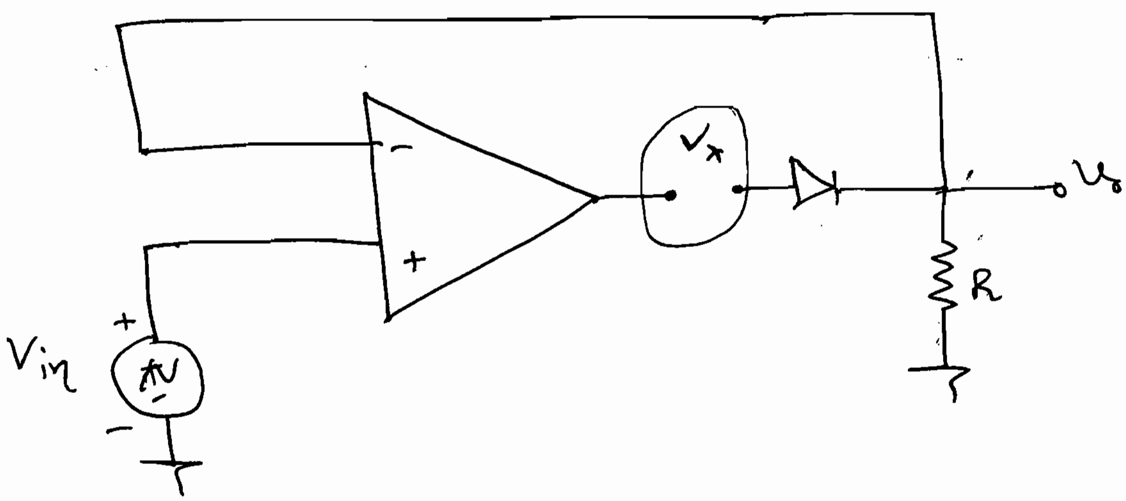


Comparator

* Precesion diode (Ideal Diode).



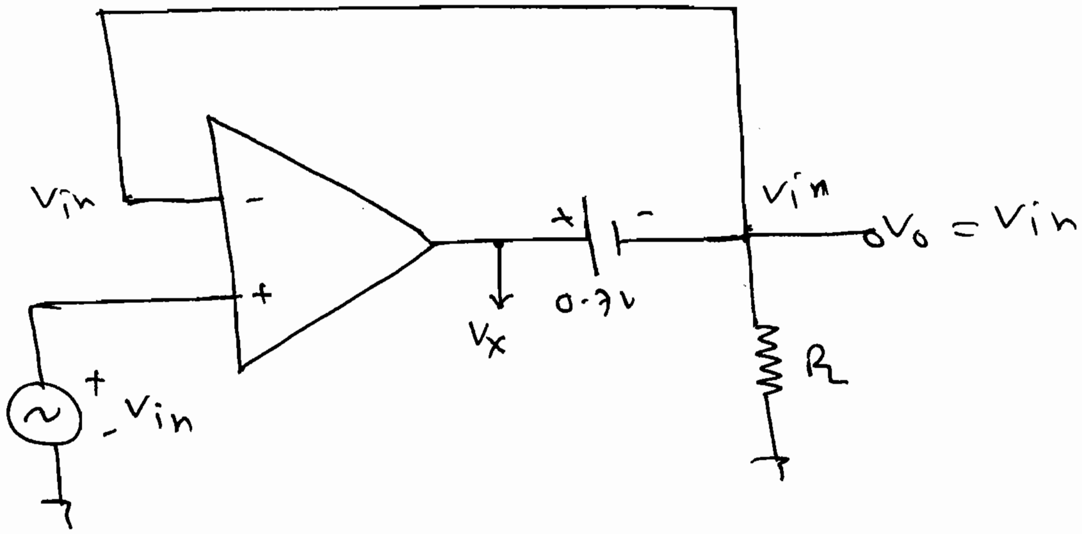
|||



Case-1 When $V_{in} > 0 \Rightarrow V_x$ is pos.

$\Downarrow$

Diode is F.B. (Neg. F/B).

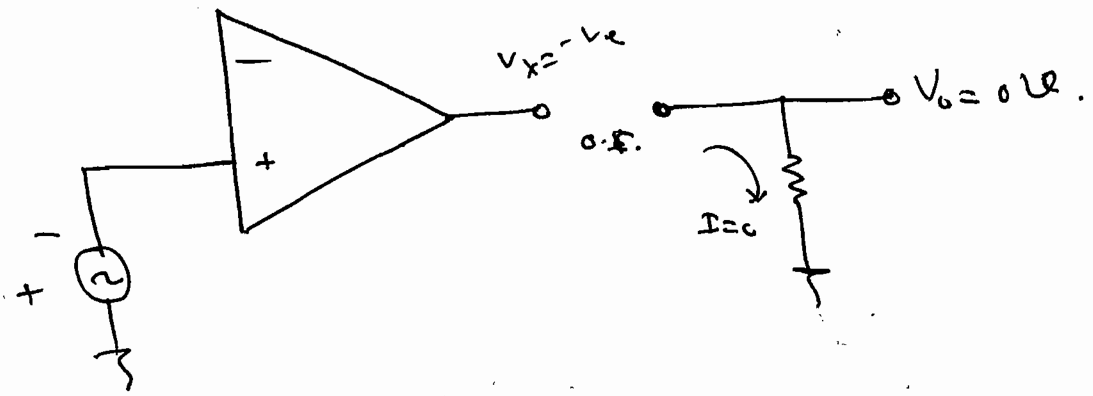


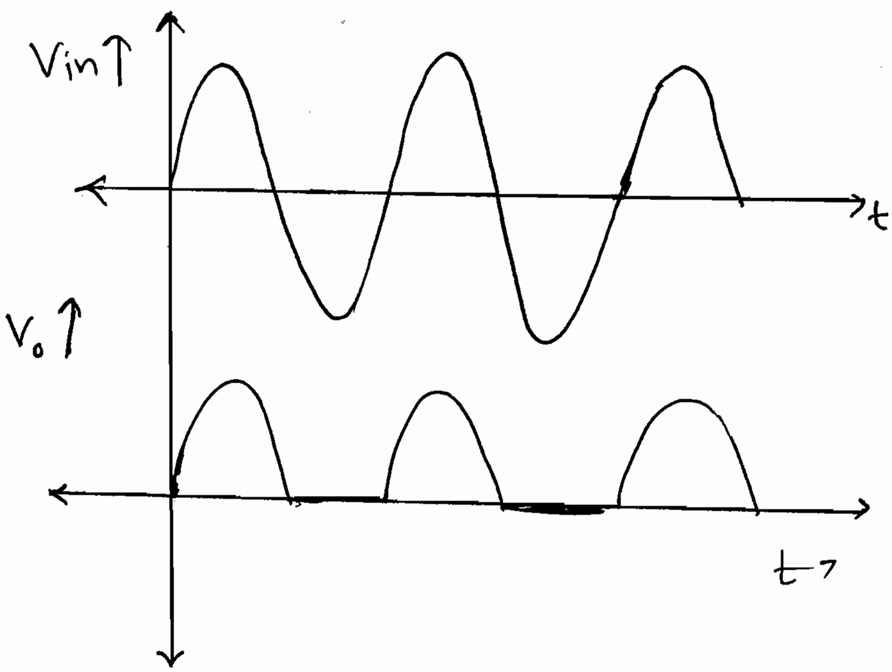
$V_0 = V_{in}$ even if $V_{in} = 1\mu V$

$V_{in} = \frac{0.7}{10^6} = 1\mu V$

$V_x = V_{in} + 0.7$.

Case-(ii) $V_{in} < 0 \rightarrow V_x$ is neg $\rightarrow$ Diode is R.B.

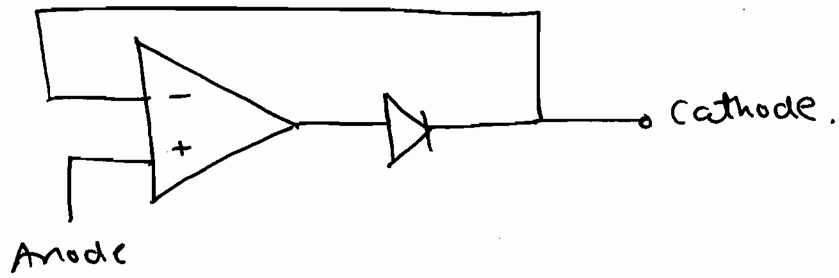




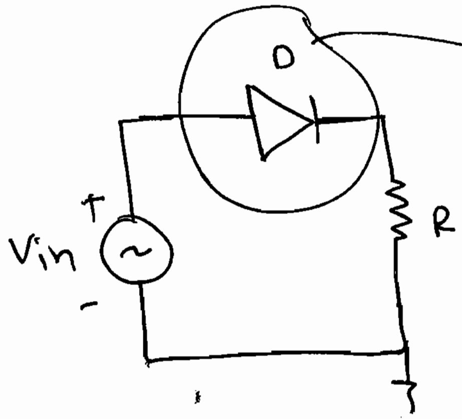
Half Wave Rectifier.

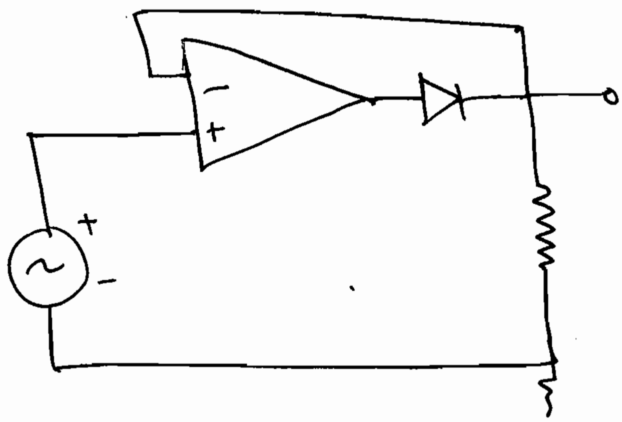
NOTE: This circuits rectifies all voltage Vin slightly greater than $\frac{0.7}{A_{OL}} \simeq \frac{0.7}{10^5} \cong 14\mu V$.

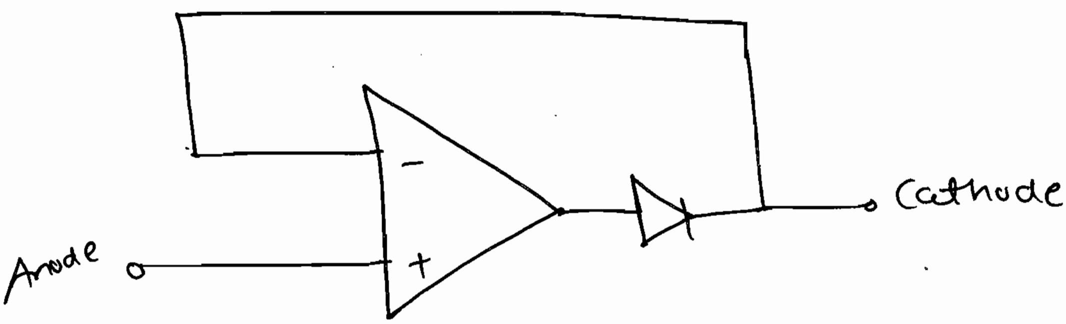
*



(ideal diode)



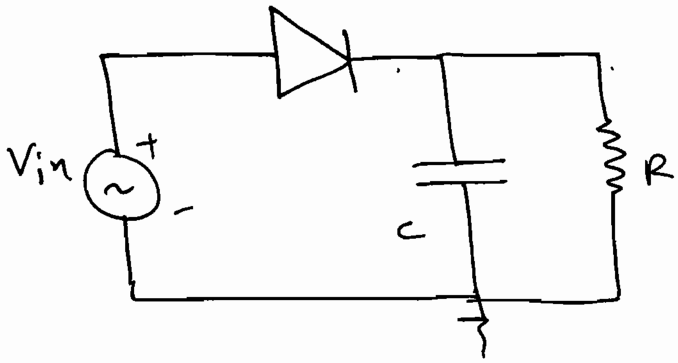




Ideal diode = op-amp + Diode.

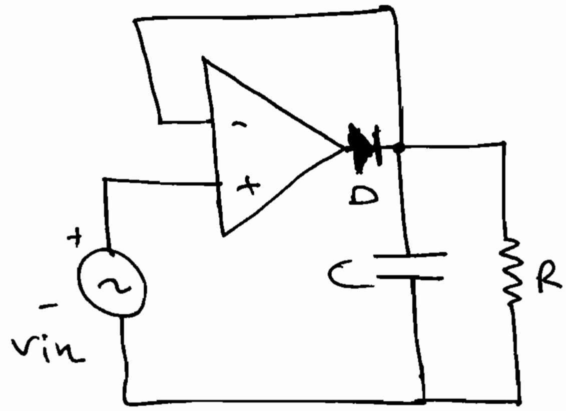
* **Peak detector (envelope detector)**

→ All Buffers have current gain.

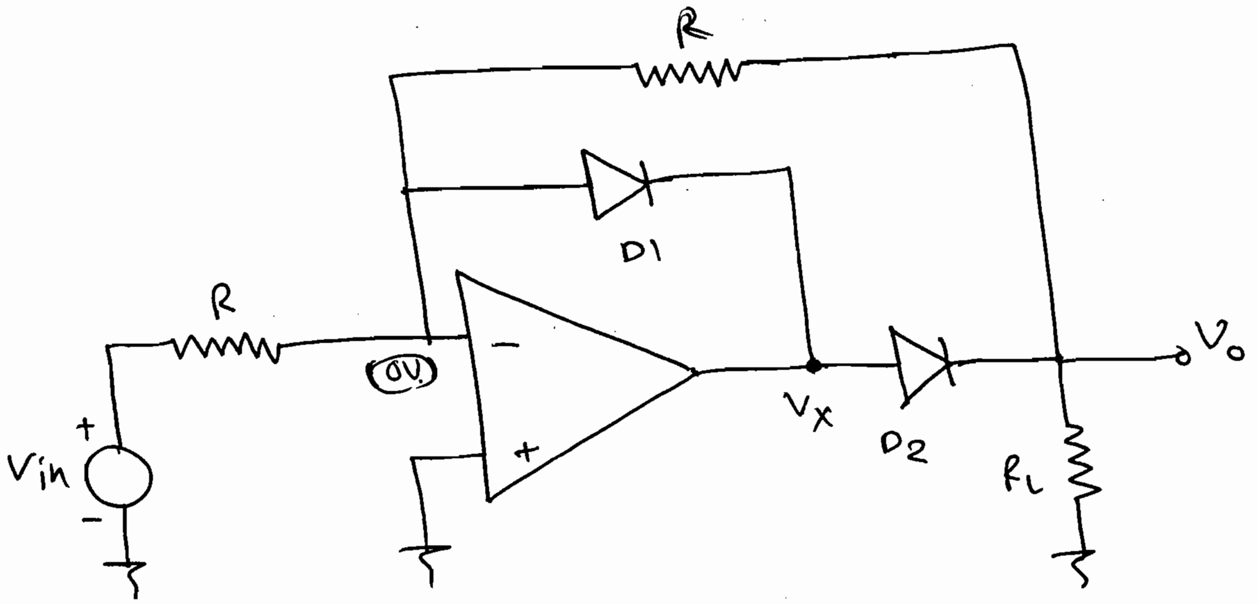


it wait till 0.7 V

≡



* **Improved Half Wave Rectifier:**



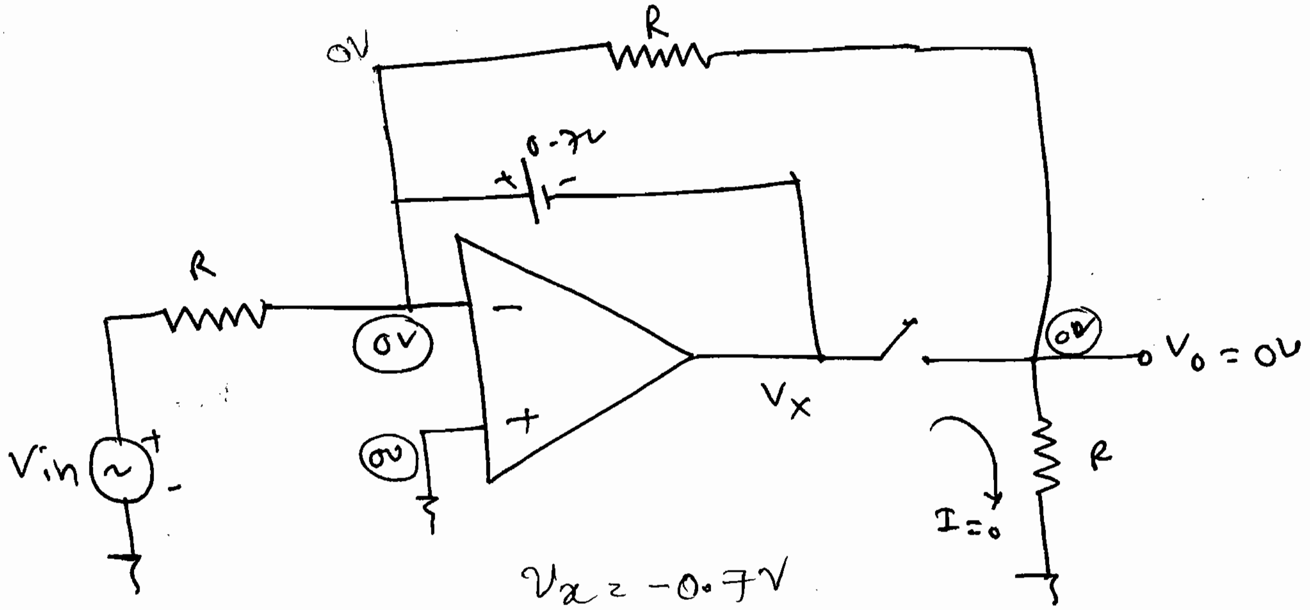
Case-(1):

When $v_{in} = +ve$

$v_x = -ve$.

So, $D_1 \rightarrow$ F.B.

$D_2 \rightarrow$ R.B.

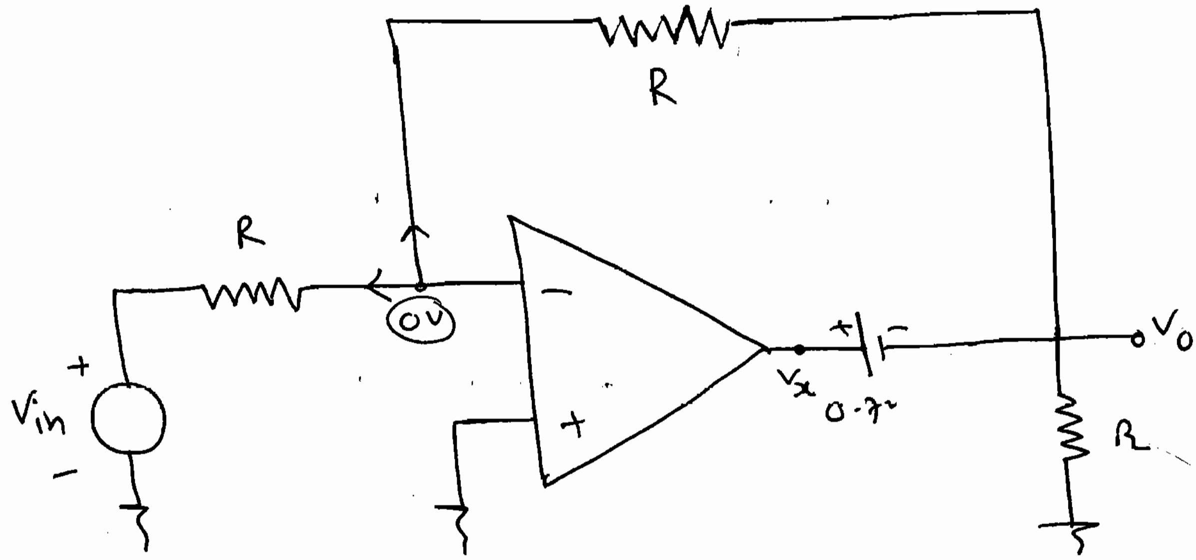


$V_x = -0.7V$

Case - 2

$V_{in} \Rightarrow -ve$; D_1 RB

$V_x \Rightarrow +ve$; D_2 FB

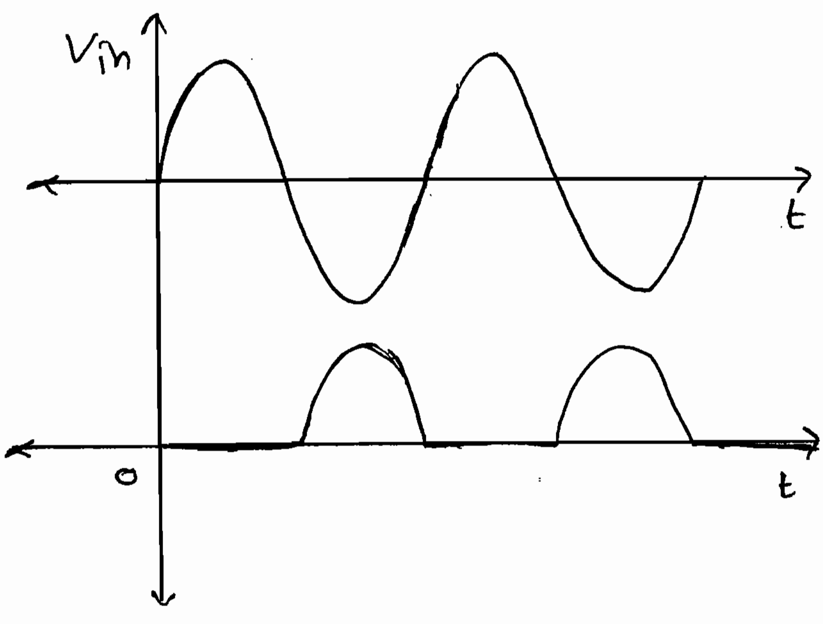


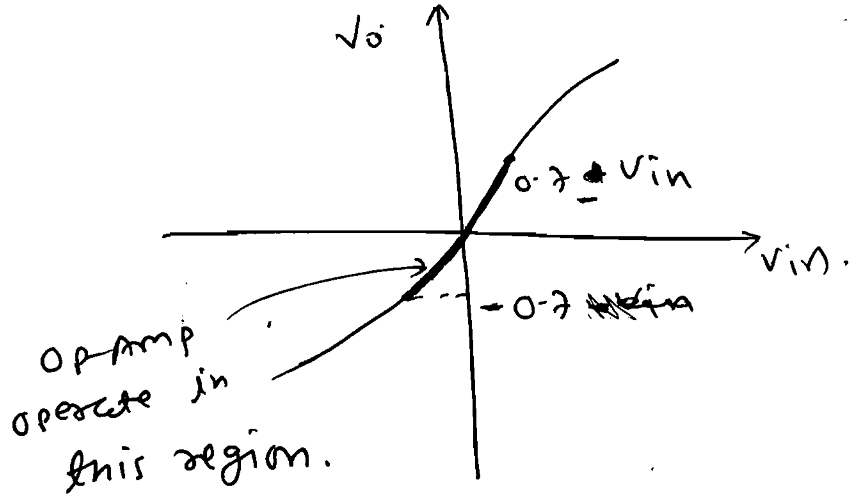
$$\frac{0 - V_{in}}{R} = \frac{0 - V_o}{R}$$

$\therefore \boxed{V_o = -V_{in}}$

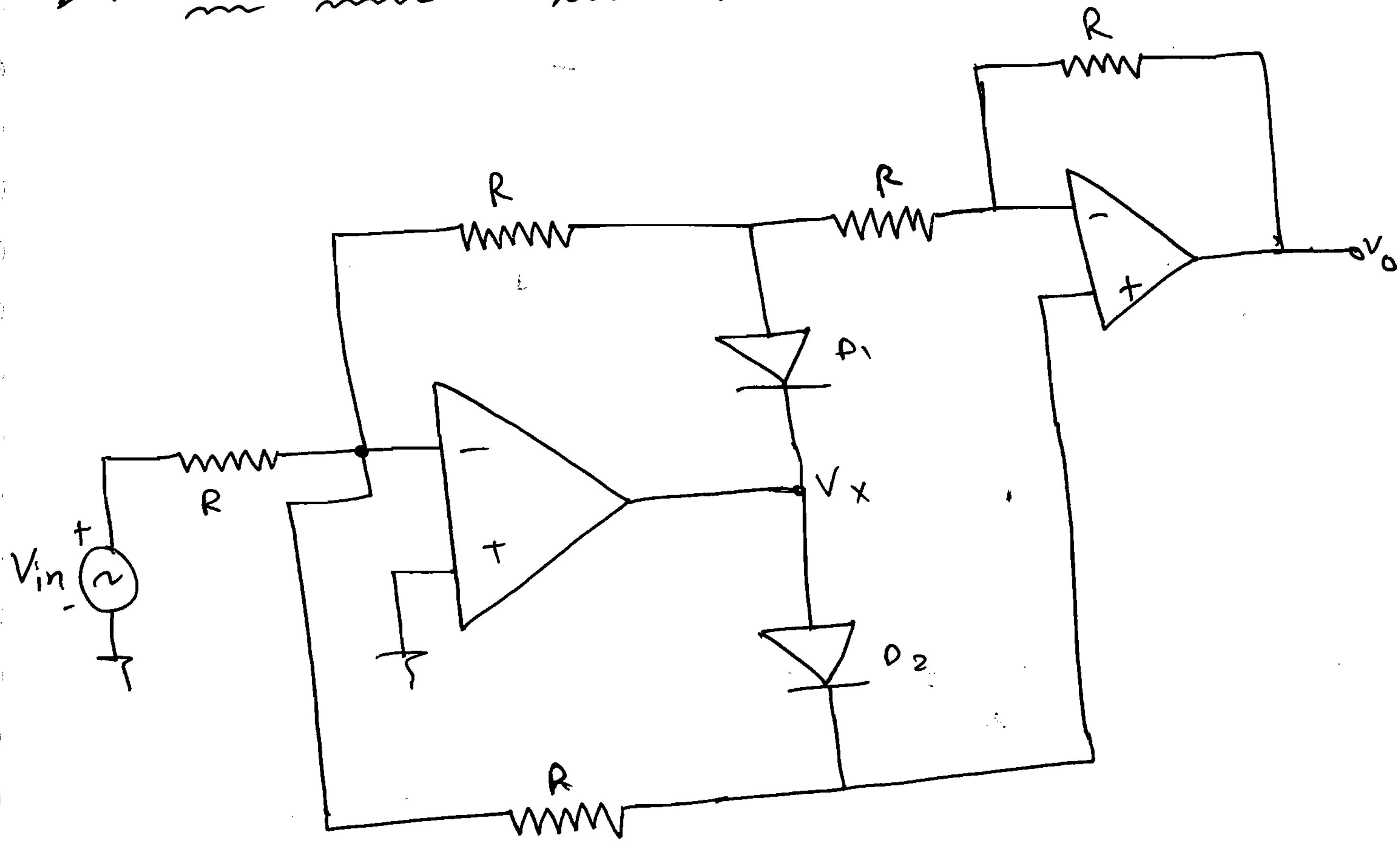
$\therefore V_x = 0.7 + V_o$

$\therefore \boxed{V_x = 0.7 \pm V_{in}}$



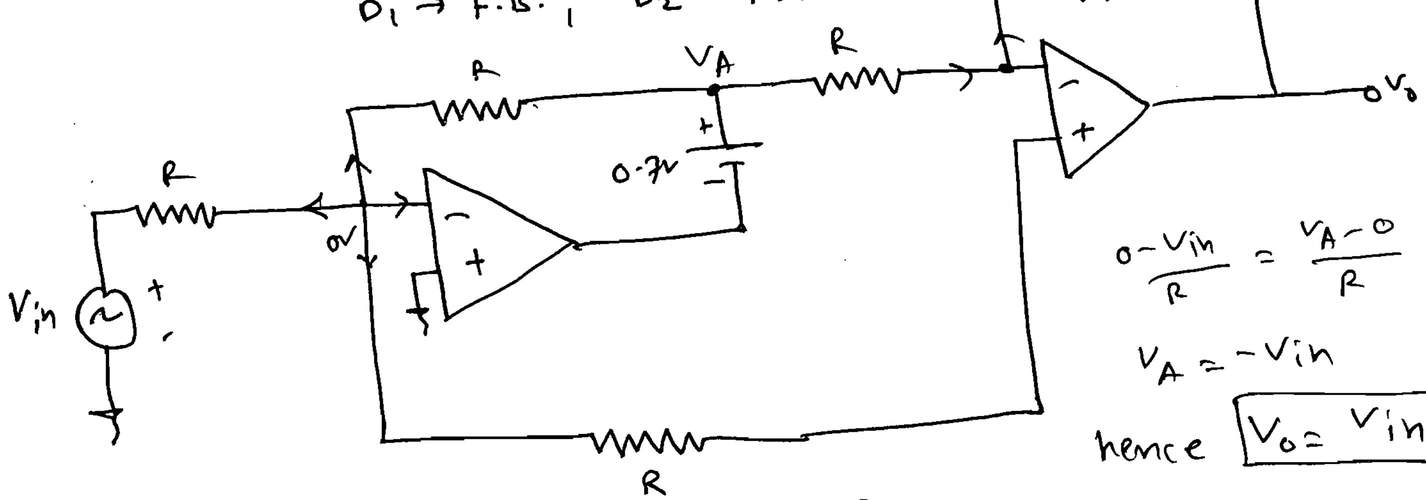


☆ Full Wave Rectifier:



case-I: Vin → positive ⇒ Vx ⇒ -ve

D1 → F.B. , D2 → R.B.



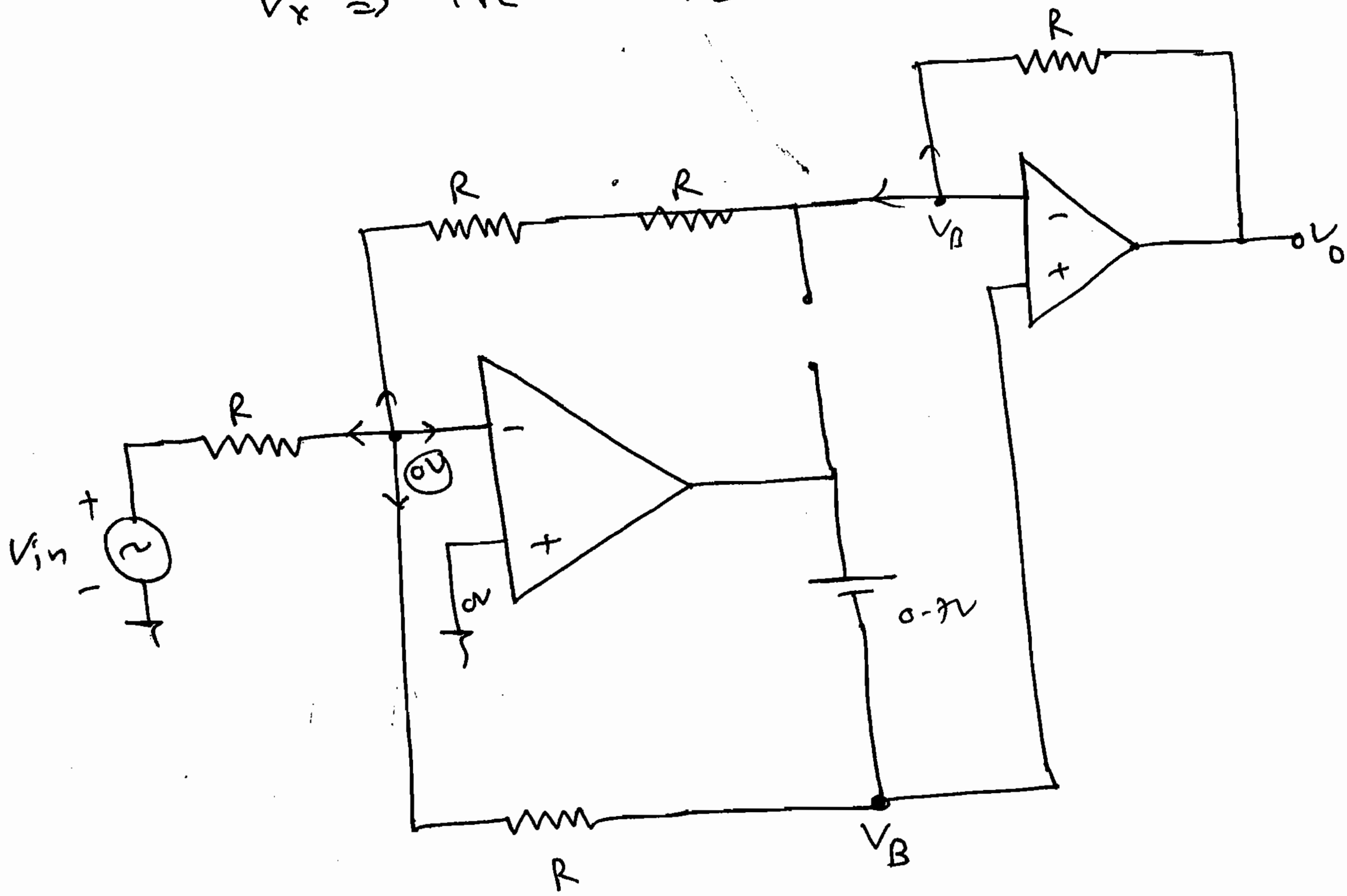
$$\frac{0 - V_{in}}{R} = \frac{V_A - 0}{R}$$

$$V_A = -V_{in}$$

hence $\boxed{V_o = V_{in}}$

Case - 2 : $V_{in} \Rightarrow -ve$ $D_1 = \text{off}$

$V_x \Rightarrow +ve$ $D_2 = \text{ON}.$



$$\rightarrow \quad \frac{0 - V_{in}}{R} + \frac{0 - V_B}{2R} + \frac{0 - V_B}{R} = 0.$$

$$\therefore \; -2V_{in} - V_B - 2V_B = 0$$

$$\therefore \quad V_B = -\frac{2}{3} \cdot V_{in}.$$

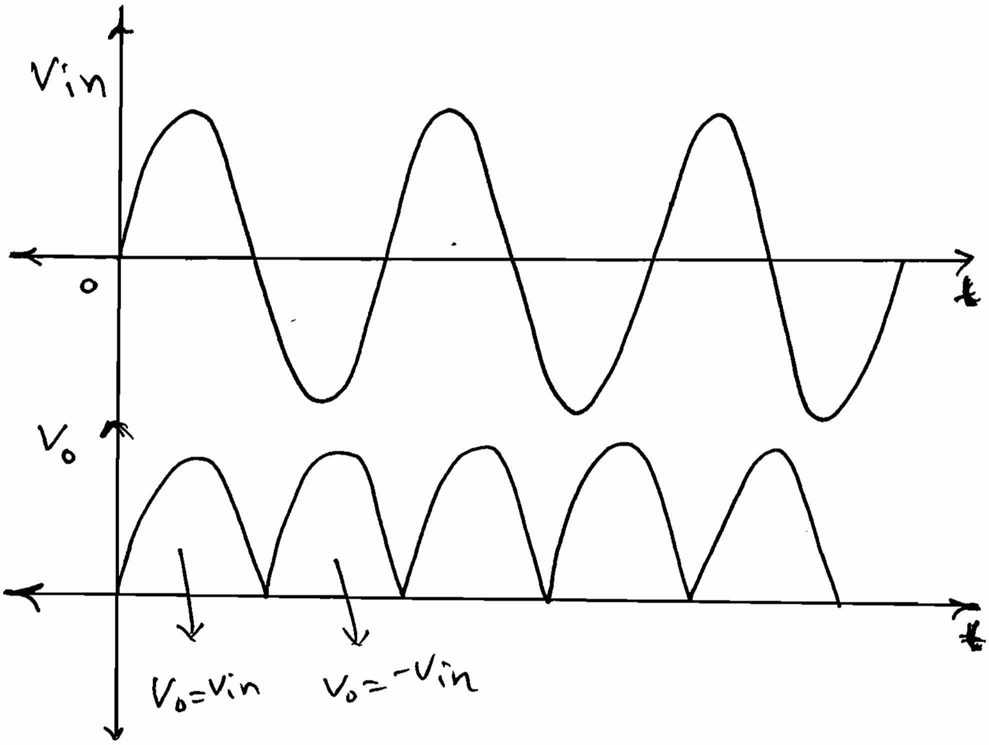
$$\rightarrow \quad \frac{V_B - 0}{2R} + \frac{V_B - V_o}{R} = 0.$$

$$\therefore \; \frac{V_B}{2R} + \frac{V_B}{R} - \frac{V_o}{R} = 0.$$

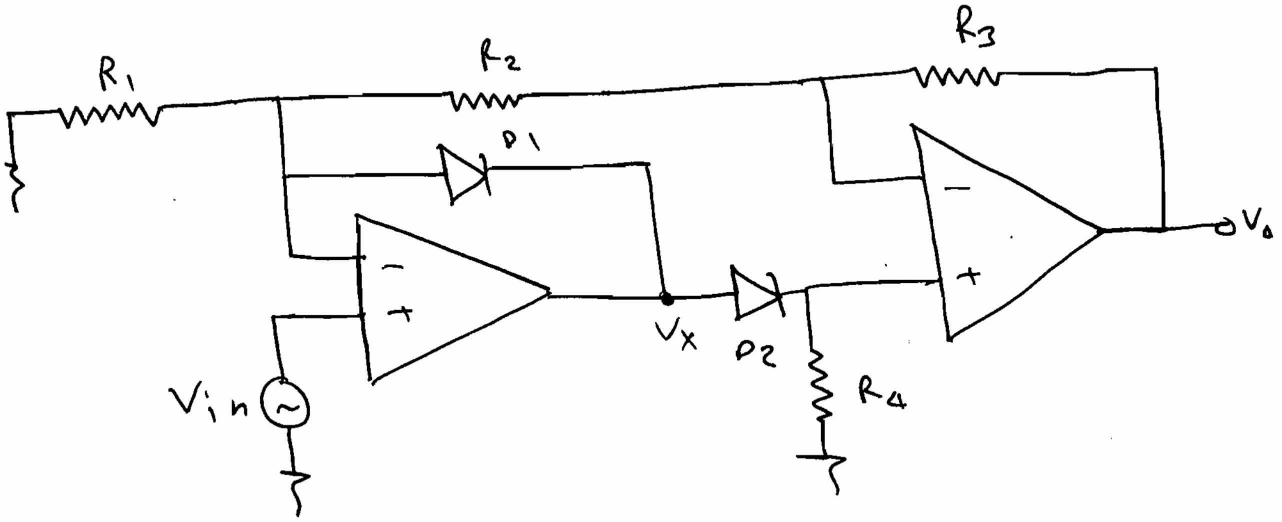
$$\therefore \; V_o = 3/2 \, V_B.$$

$$\therefore \; V_o = 3/2 \left(-2/3 \cdot V_{in}\right)$$

$$\therefore \; \boxed{V_o = -V_{in}}$$

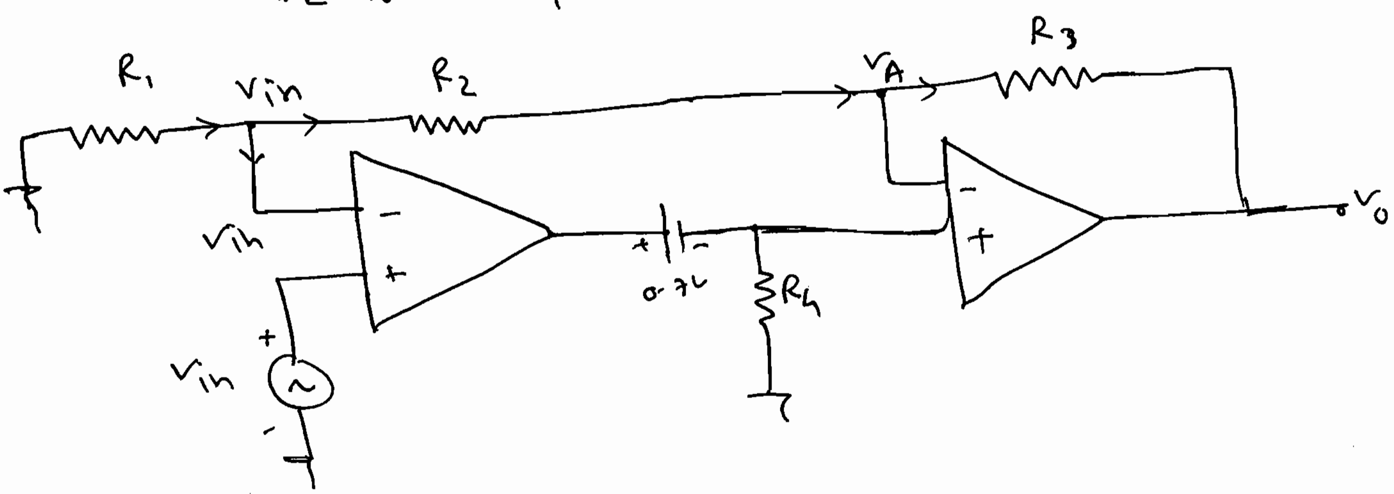


Ex-1: Find V_o if V_{in} = +ve & V_{in} = -ve.



Ans: (i) When V_{in} = +ve ⇒ V_x = +ve.

D_2 is FB, $D_1 \rightarrow$ RB.



$$\frac{0 - V_{in}}{R_1} = \frac{V_{in} - V_a}{R_2}.$$

$$\frac{V_a}{R_2} = \frac{V_{in}}{R_2} + \frac{V_{in}}{R_1}. \quad — ①$$

$$\therefore \frac{V_{in} - V_A}{R_2} = \frac{V_A - V_o}{R_3}.$$

$$\therefore \frac{V_{in}}{R_2} = \frac{V_A}{R_2} + \frac{V_A}{R_3} - \frac{V_o}{R_3}.$$

$$\therefore V_A \left[\frac{R_2 + R_3}{R_2 \cdot R_3} \right] = \frac{V_{in}}{R_2} + \frac{V_o}{R_3}.$$

$$\therefore V_A = \left[\frac{V_{in}}{R_2} + \frac{V_o}{R_3} \right] \times \frac{R_2 \cdot R_3}{R_2 + R_3} \quad — ②$$

$\therefore$ Put ② in ①

$$\frac{R_3}{R_2 + R_3} \left[\frac{V_{in}}{R_2} + \frac{V_o}{R_3} \right] = V_{in} \left[\frac{R_1 + R_2}{R_2 \cdot R_1} \right].$$

$$\therefore \frac{R_3}{R_2(R_2 + R_3)} V_{in} + \frac{V_o}{R_2 + R_3} = V_{in} \left[\frac{R_1 + R_2}{R_2 \cdot R_1} \right].$$

$$\therefore \frac{0 - V_{in}}{R_1} = \frac{V_{in} - V_o}{R_2 + R_3}.$$

$$\therefore -V_{in} (R_2 + R_3) = R_1 (V_{in}) - R V_o.$$

$$\therefore R_1 V_o = V_{in} (R_1 + R_2 + R_3).$$

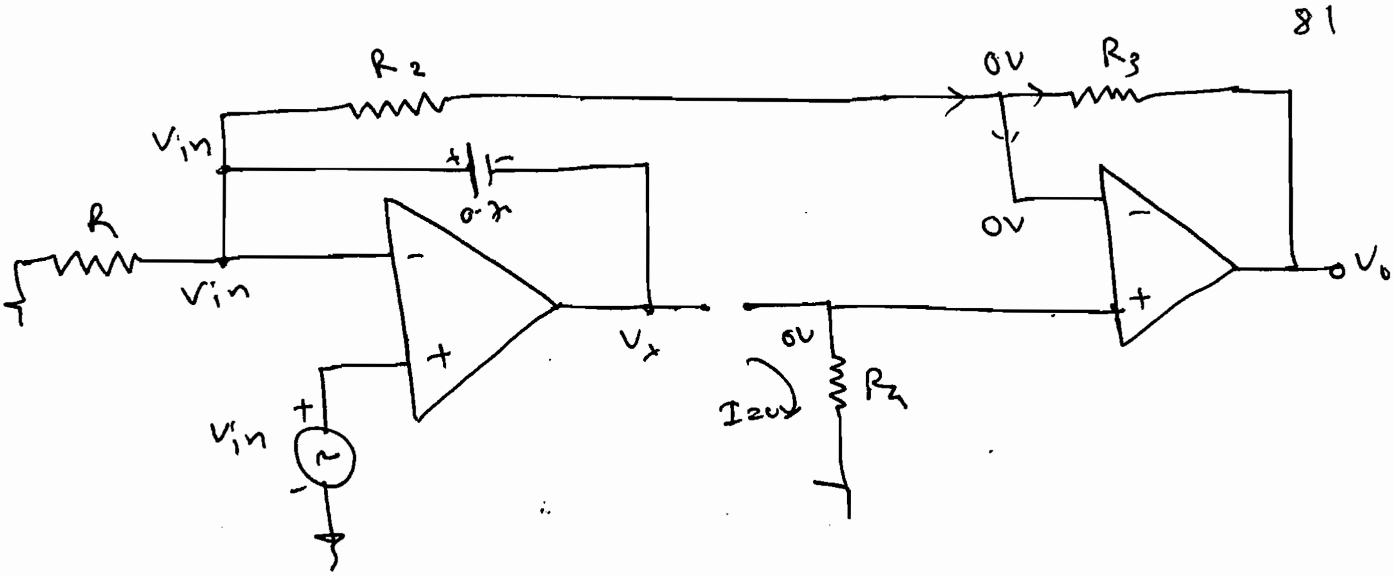
$$\therefore \boxed{V_o = \frac{R_1 + R_2 + R_3}{R_1} V_{in}}$$

② when $V_{in} = -ve.$

$V_x \Rightarrow +Ve.$

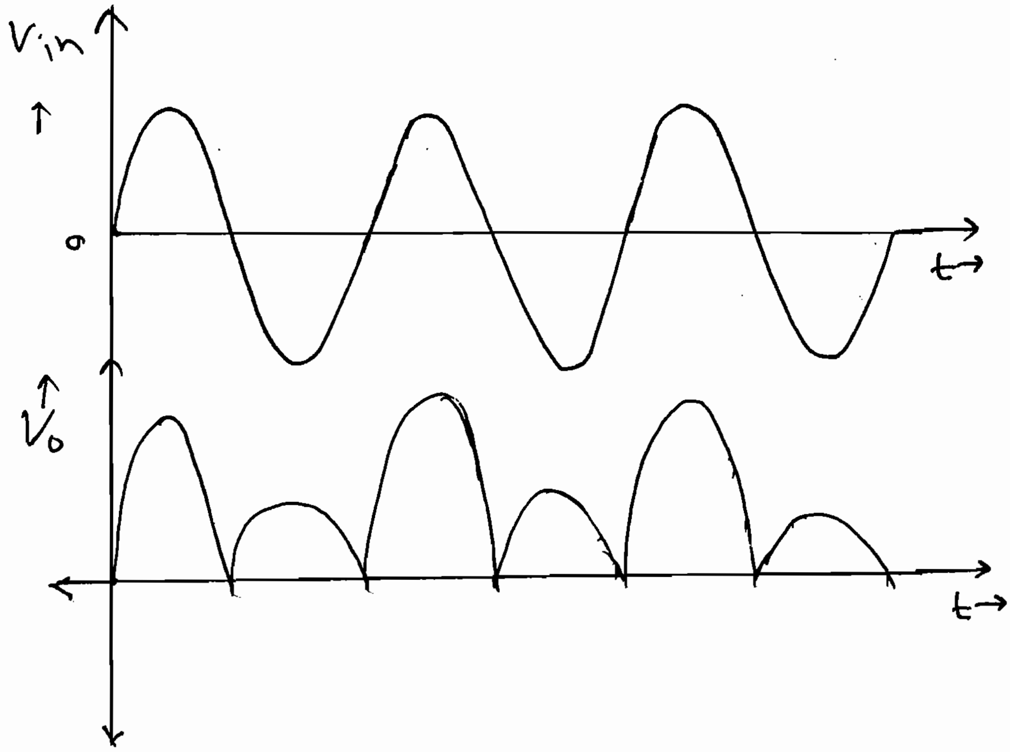
$D_2 \rightarrow$ R.B.

$D_1 \rightarrow$ F.B.

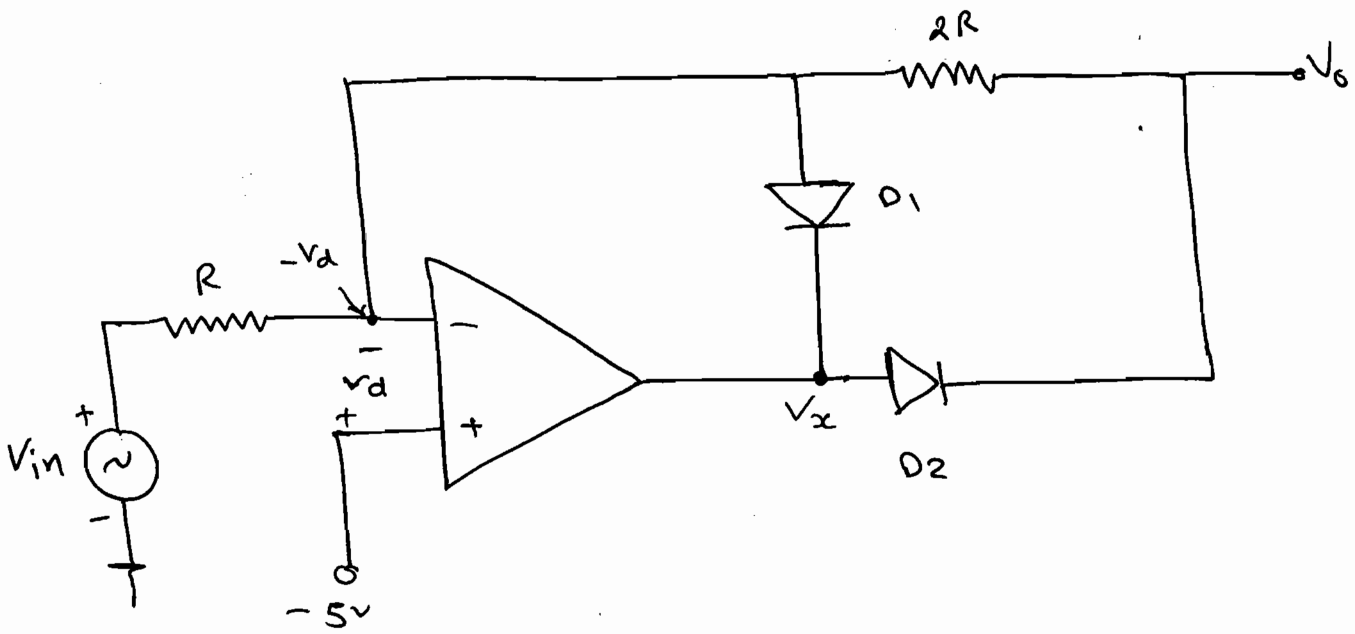


$$\therefore \quad \frac{V_{in} - 0}{R_2} = \frac{0 - V_0}{R_3}.$$

$$\therefore \quad \boxed{\frac{V_0}{V_{in}} = -\left(\frac{R_3}{R_2}\right)} \Rightarrow \quad V_0 = -\left(\frac{R_3}{R_2}\right) V_{in}.$$



Ex-2

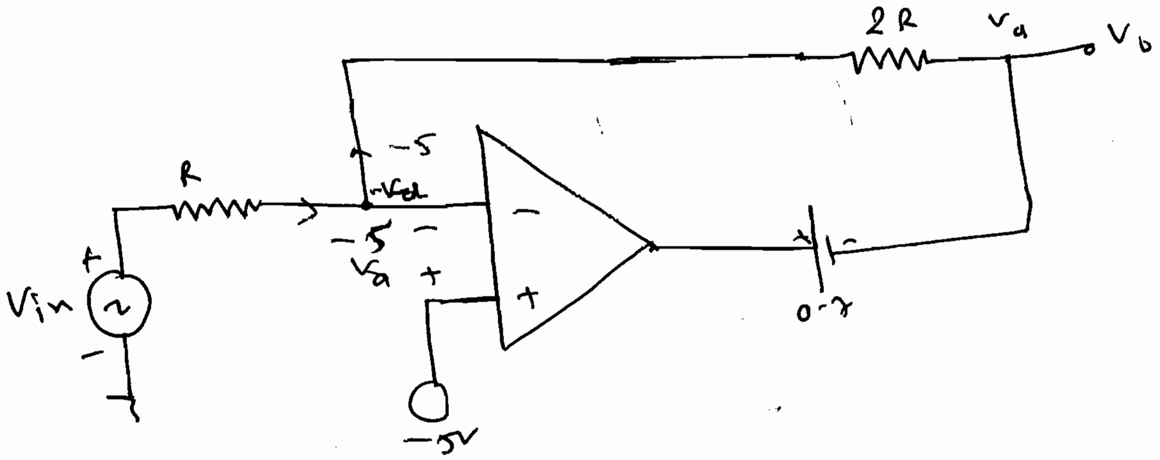


Ans: Case-(ii) $\quad V_d > 0, \quad V_d = -V_{in} - 5 > 0$

$V_{in} < -5\,V.$

$V_d > 0 \Rightarrow V_x = +ve.$

$\therefore$ $D_1 \rightarrow$ R.B. , $D_2 \rightarrow$ F.B.



$$\therefore \frac{V_{in} - (-V_d)}{R} = \frac{-V_d - V_0}{2R}. \qquad V_d = 5.$$

$$\therefore 2V_{in} + 2V_d = -V_d - V_0$$

$$3V_d = -V_0 - 2V_{in}.$$

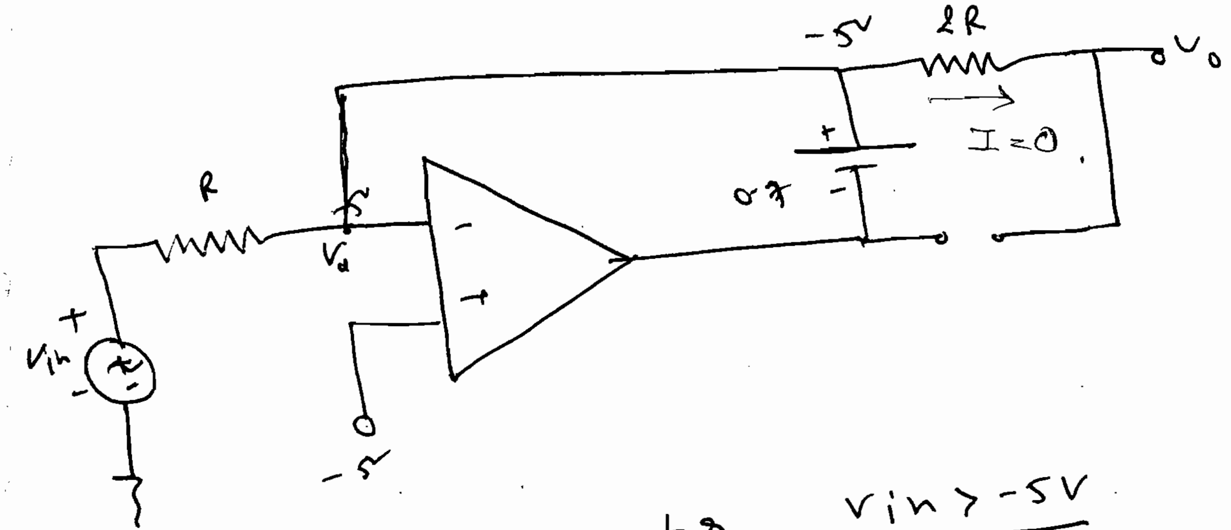
$$15 = -V_0 - 2V_{in}.$$

$$\therefore \boxed{V_0 = -(15 + 2V_{in})} \quad \text{for } V_{in} < -5.$$

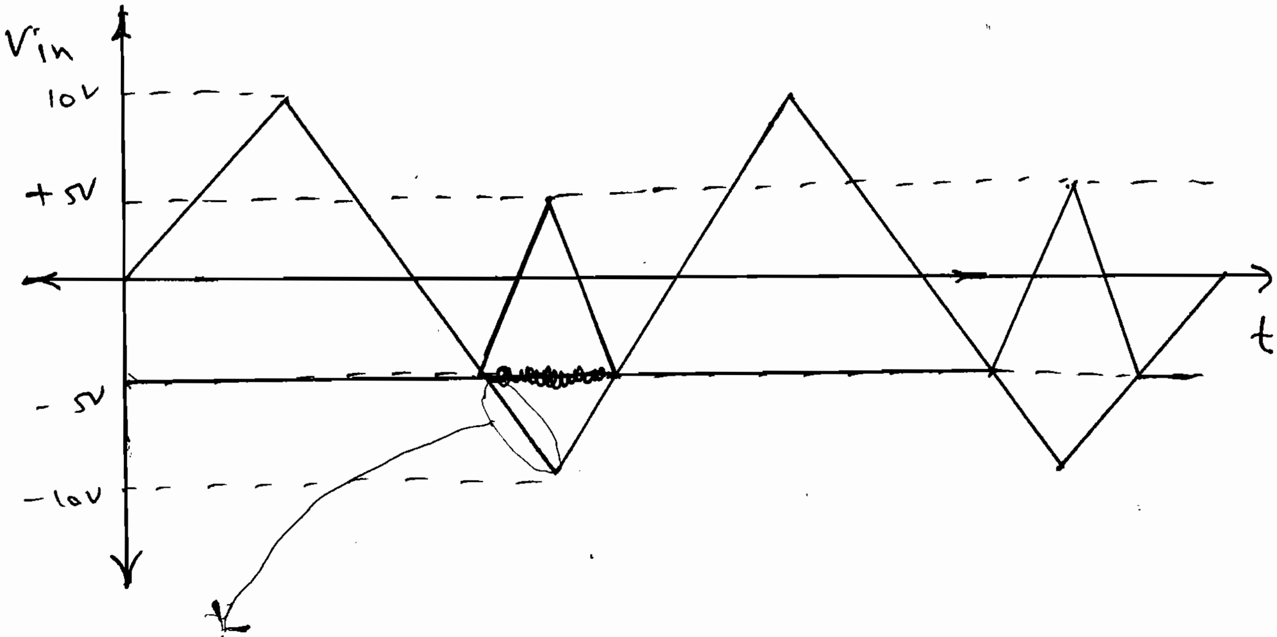
(2)

$V_{in} > -5 \Rightarrow \quad D_1 = $ F.B. $\quad V_x = -ve$

$\therefore V_d < 0 \qquad D_2 = $ R.B.



So, $V_0 = -5V$ for $v_{in} > -5V$

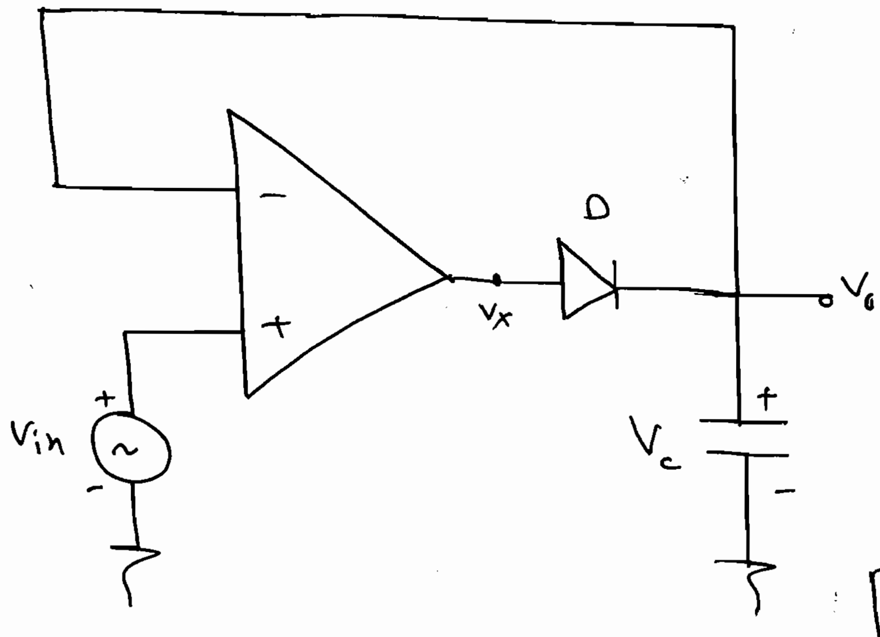


$v_{in} < -5 \Rightarrow$

V_{in}	$v_0 = -(2V_{in}+15)$
-5	-5
-6	-3
-7	-1
-8	+1
-9	+3
-10	+5

* Peak Detector:

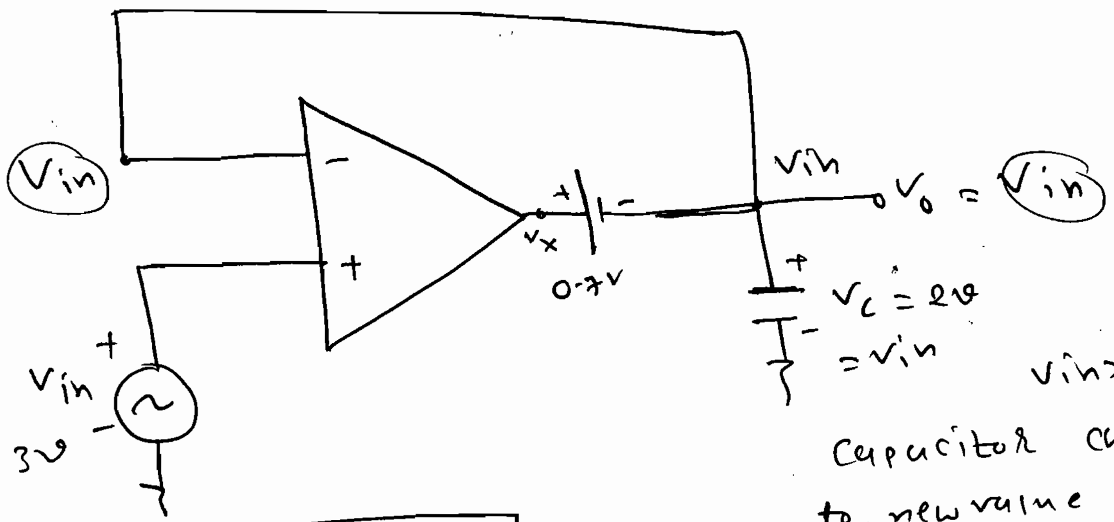
⇒



$$\boxed{V_x = V_{in} + V_c.}$$

⇒ Case (i): when $V_{in} > V_c$. V_x is +ve.

D → F.B.



vin>vc

capacitor charges to new value vin>vc i.e. 3v.

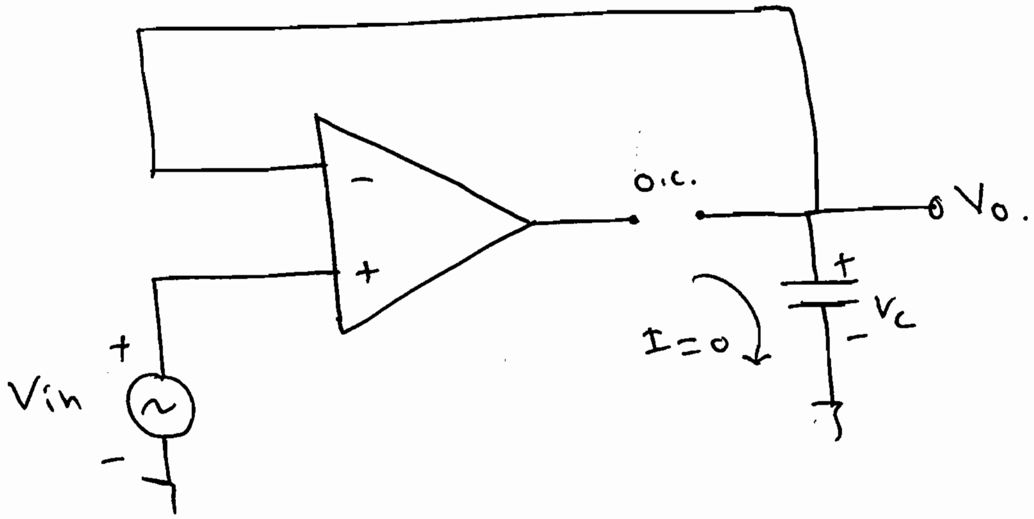
$$\boxed{V_o = V_{in}.}$$

∴

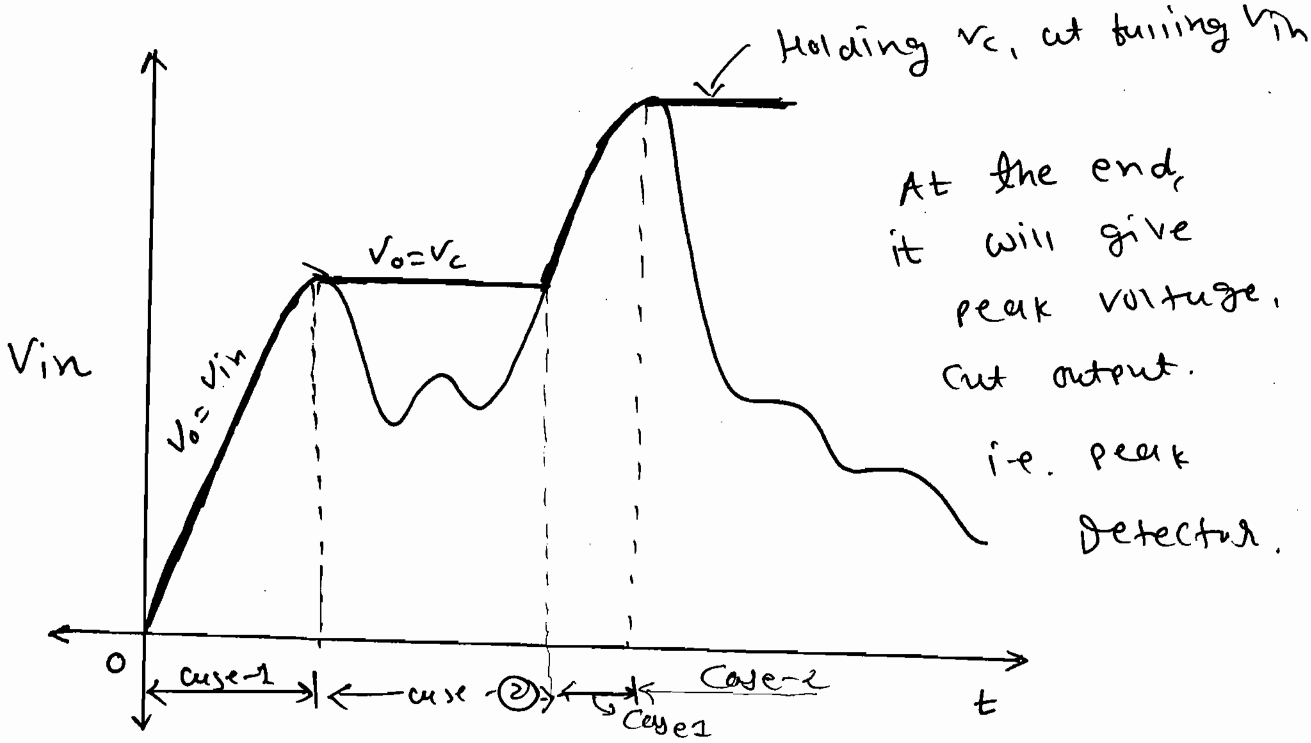
case-2: when $V_{in} < V_c$.

∴ D → R.B. (∵ V_x = -ve).

diode → R.B.

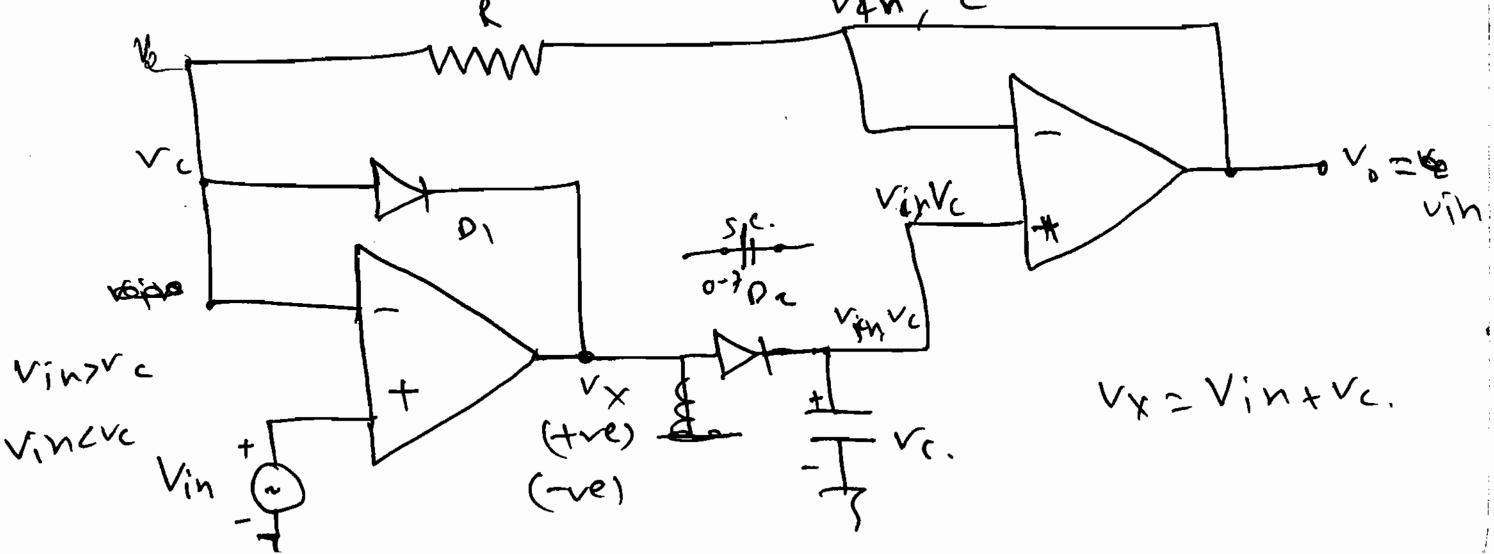


so, $\boxed{V_o = V_c}$ until next $V_{in} > V_c$.



At the end, it will give peak voltage, at output. i.e. peak Detector.

* Improved peak Detector:

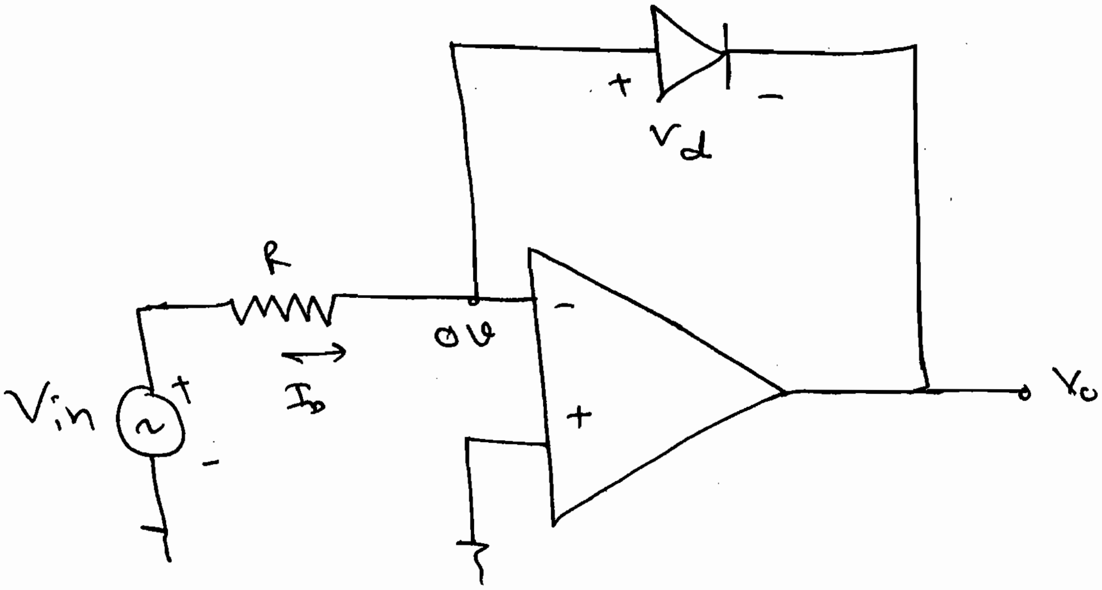


$V_x = V_{in} + V_c$.

☆ Log Amplifier:

$$I_d = I_s e^{V_d/V_t}$$

$$V_d = V_t \ln\left(\frac{I_D}{I_s}\right)$$



$\therefore I_D = \frac{V_{in} - 0}{R}$

$I_D = \frac{V_{in}}{R}$.

$\therefore 0 - V_o = V_d.$

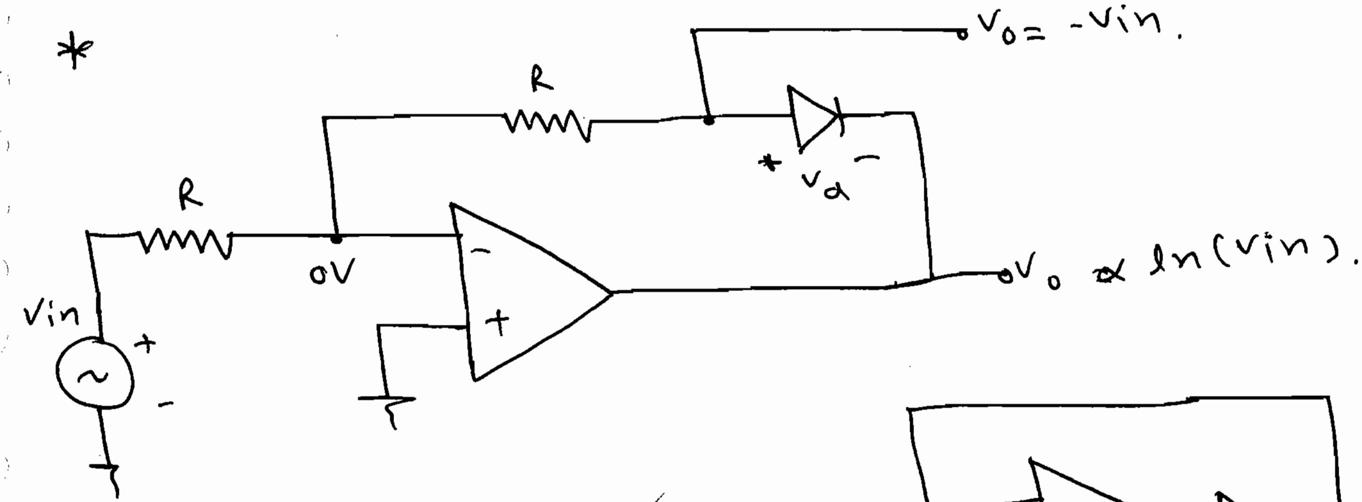
$\therefore \boxed{V_D = -V_o}$

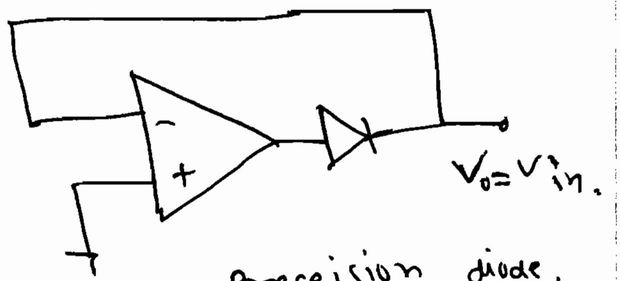
Now, $V_d = V_t \ln\left(\frac{I_D}{I_s}\right)$

$\therefore V_o = -V_t \ln\left[\frac{V_{in}}{R I_s}\right].$

$\therefore \boxed{V_o \propto \ln(V_{in})}$

*





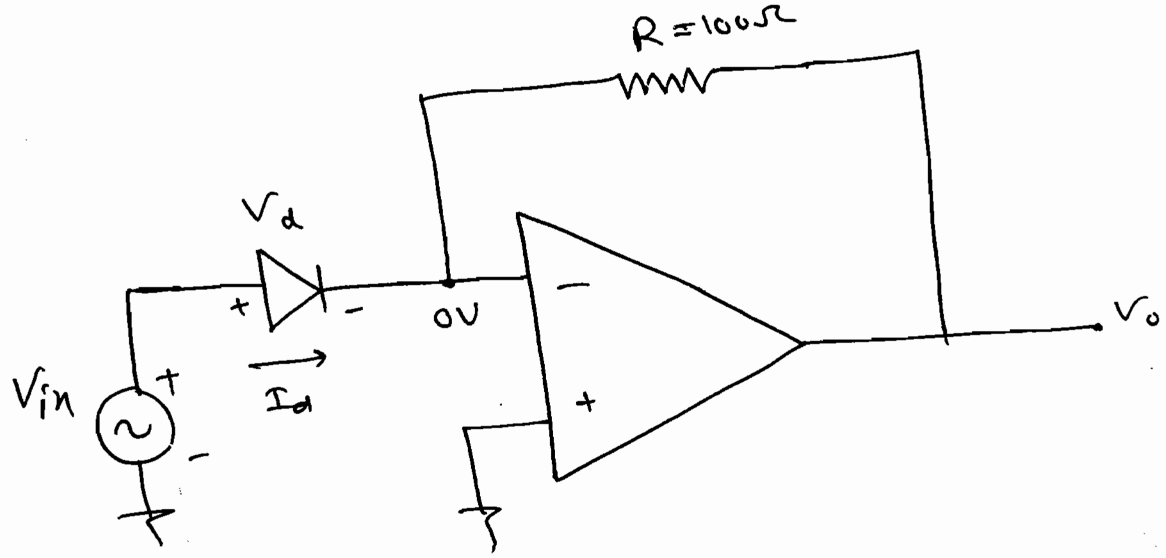
Precision diode.

$$\frac{0 - V_{in}}{R} + \frac{0 - V_0}{R} = 0.$$

$\therefore$ $\boxed{V_0 = -V_{in}}$

→ If we involve V_d in o/p then it is log operation otherwise precesion diode.

Exponetial Amplifier:



$$\therefore \quad I_D = \frac{0 - V_0}{R}.$$

$$\therefore \quad V_0 = -R I_D$$

$$\therefore \quad V_0 = -R I_s e^{V_D/V_t}.$$

$$\therefore \quad V_0 = -R I_s e^{v_{in}/v_t}$$

But $V_d = V_{in}$

$$\boxed{V_0 \propto e^{v_{in}}}$$

Now $\eta = 1$, $V_t = 25mV$, $I_s = 10^{-13}$ A, $V_{in} = 0.68$

$$\therefore V_0 = -100 \times 10^{-13} \left[e^{\frac{0.68}{25 \times 10^{-3}}} \right].$$

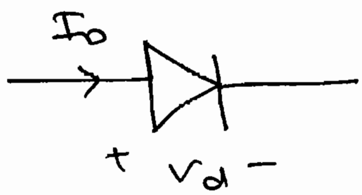
$$\therefore \boxed{V_0 = -6.5\,V}$$

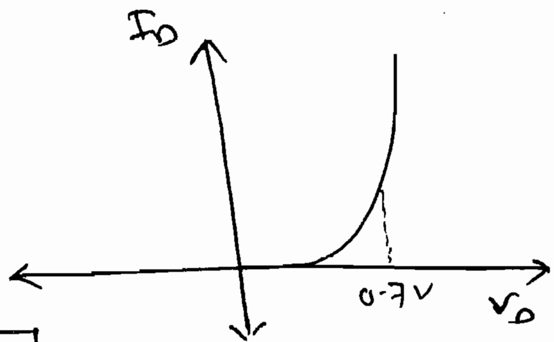
☆ Small Signal Analysis :-

→ Amp is linear operation.

→ Nonlinear devices are as follow:

(1) Diode:

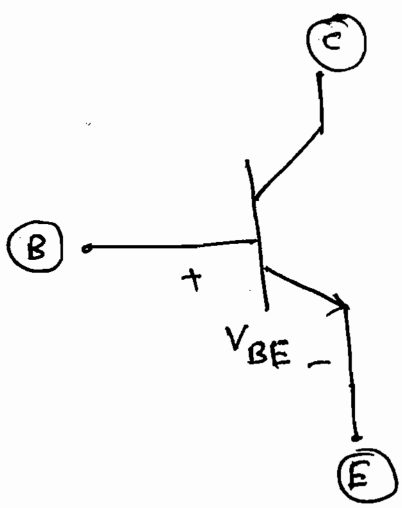


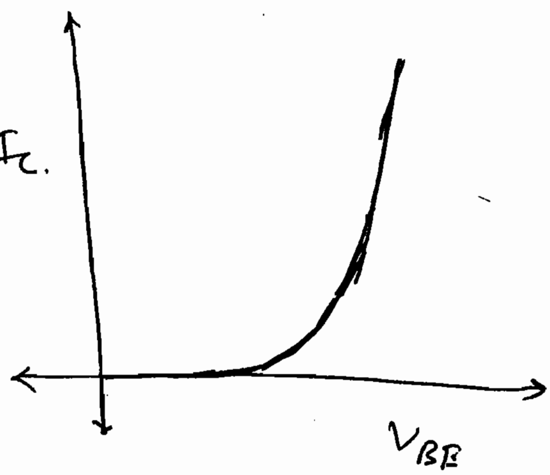


$$\boxed{I_D = I_s \cdot e^{V_d / V_t}}$$

(2)

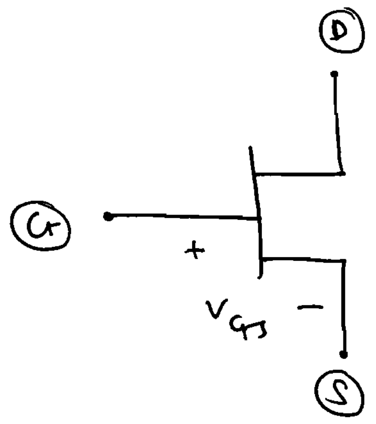
BJT:

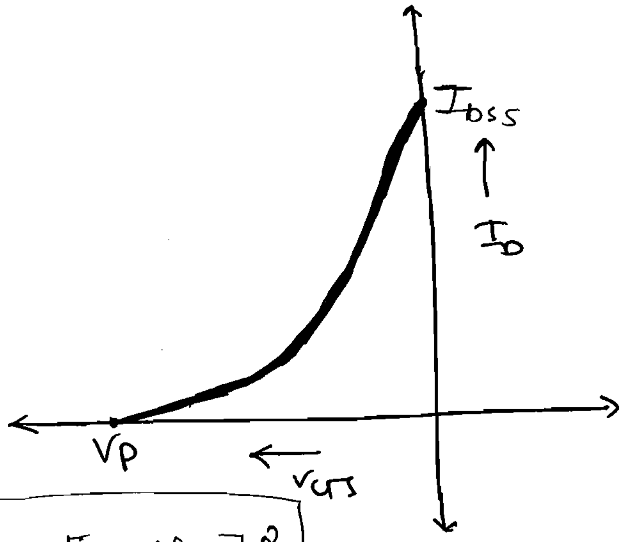




$$\boxed{I_C = I_s \cdot e^{V_{be} / V_t}}$$

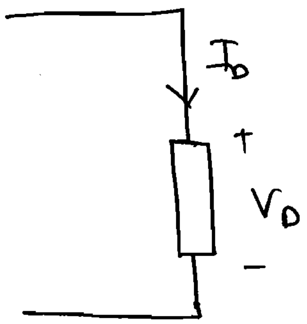
③ FET:



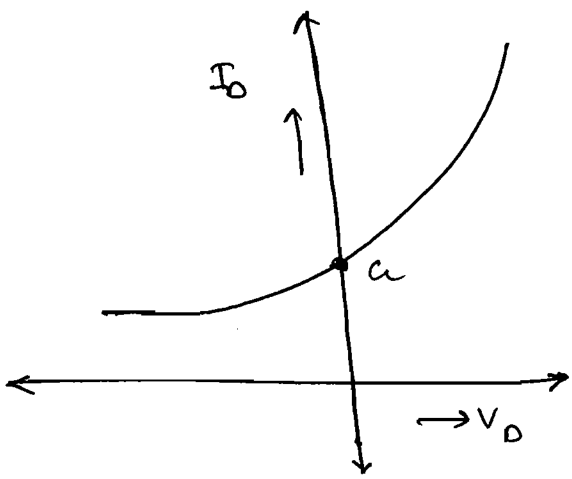


$$\boxed{I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2}$$

*



$$\boxed{I_D = a e^{bV_D}}$$

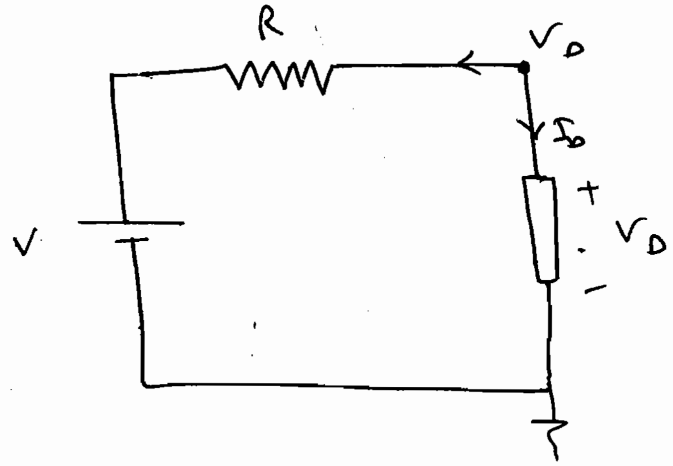


*

KVL, KCL

linear	Non-linear
Thevinian	
Norton	
Superposition	

* Dc Analysis:



KCL,

$$\frac{V_D - V}{R} + I_D = 0 \quad \text{—(1)}$$

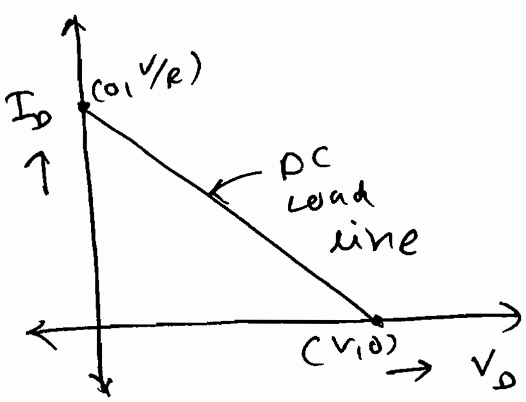
Now, $I_D = ae^{bV_D}$

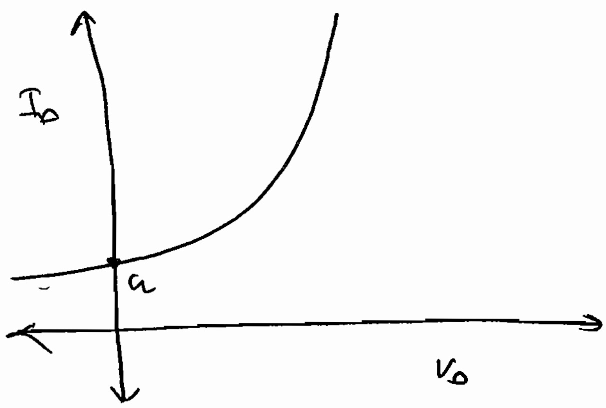
$$\therefore \boxed{\frac{V_D - V}{R} + ae^{bV_D} = 0.}$$

Solve By (1) trial and error.

(2) Iteration [Numerical method].

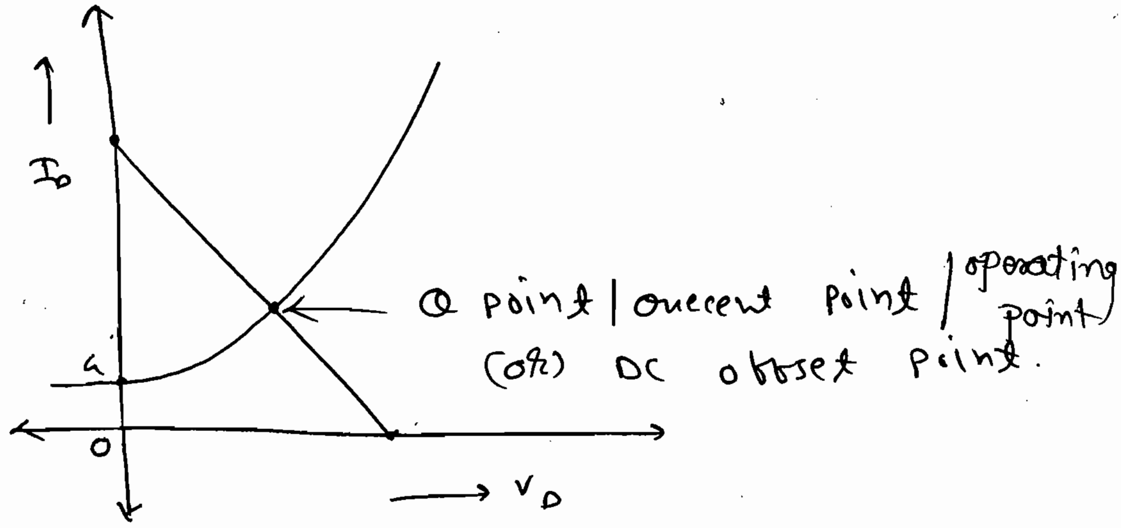
* graphical:





V_D	I_D
V	0
0	V/R

*



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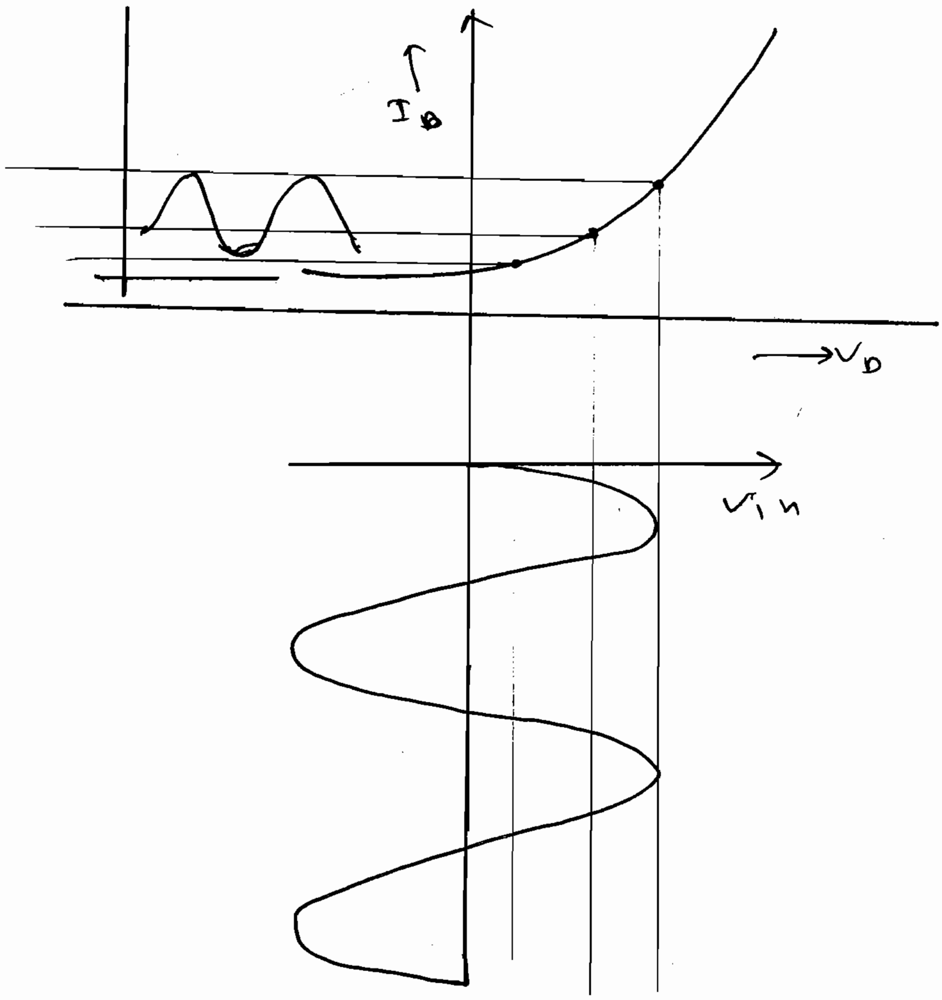
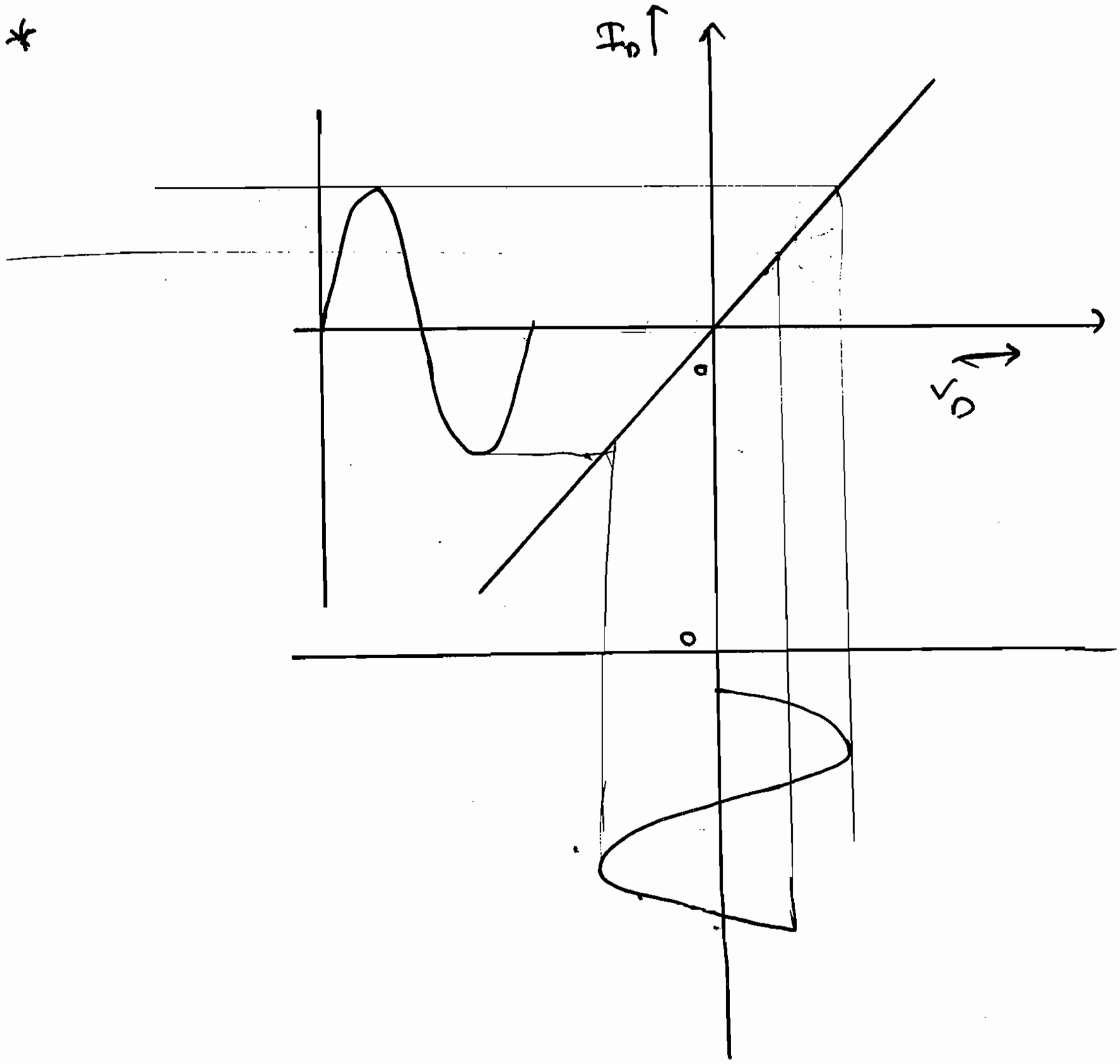


→ In order to get same shape at output, the characteristic must be linear. So, BJT, and ~~has~~ an active device has non-linear device and they do not gave same shape as input is very large. So some sol^n is required.

*



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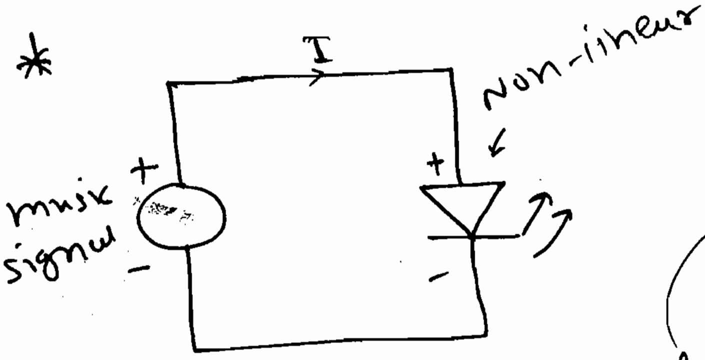
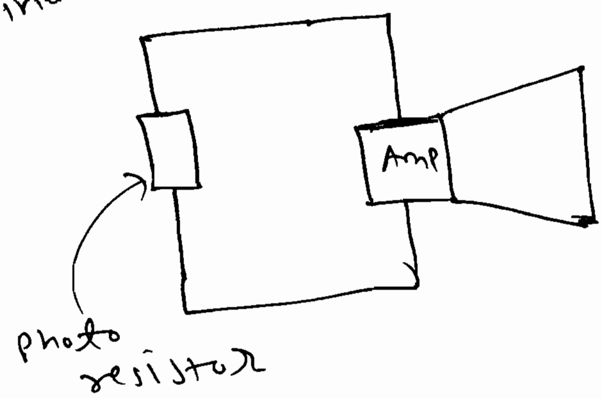
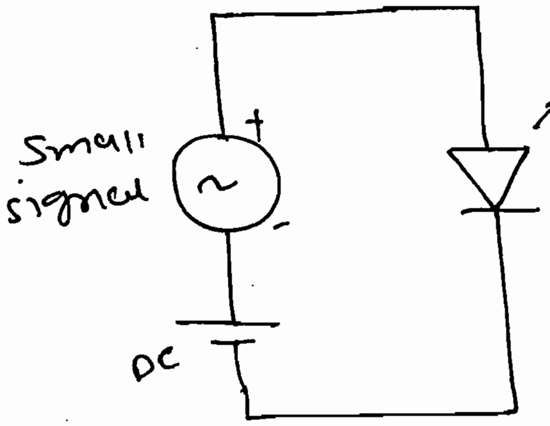


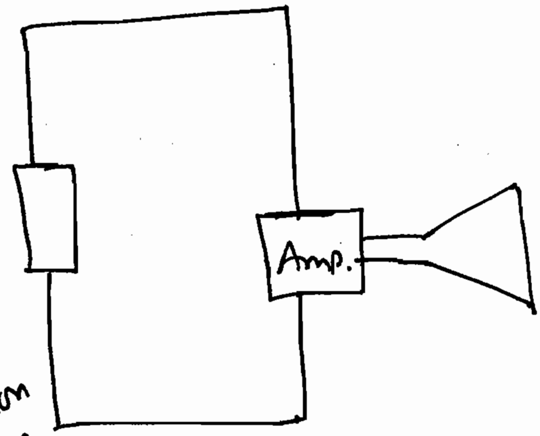


→ In order to get same shape of input at output (Amplified), Amp should follows the same shape of photo resistor and in order to do this photo resistor should follow shape available at LED and LED should follow input shape

→ so, this is the linear operation then o/p is same as the input.

Correction:

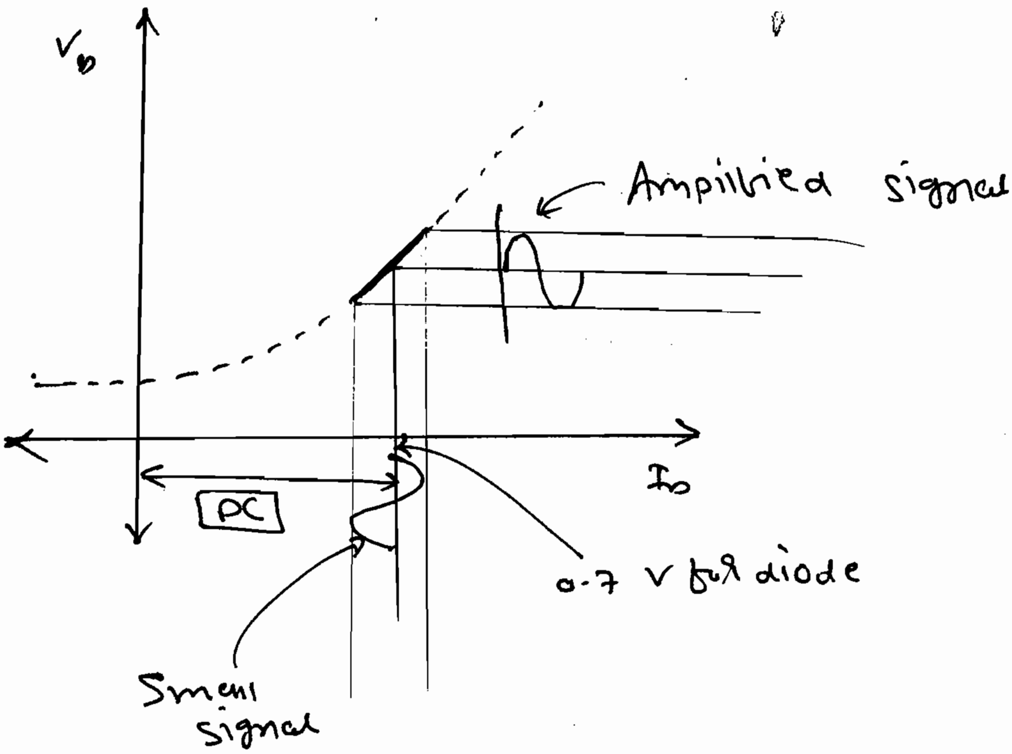




→ linear
Superposition theorem and thevinian.

adding dc = biasing.

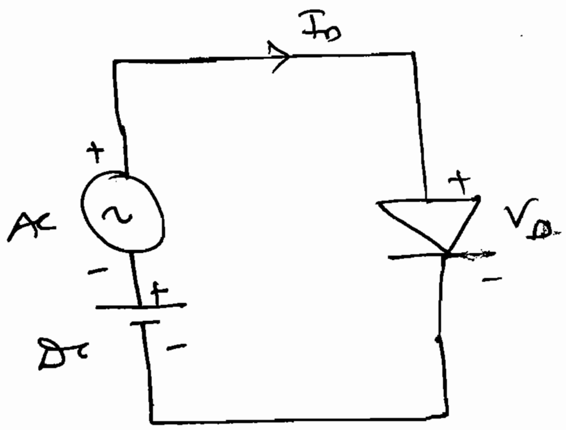
→ Now, All devices has same shape or voltage which is at input.



✩ Small Signal Analysis :

1) Add DC
2) keep the signal Small.
3) non linear ⇒ linear.

* Small signal Analysis of Diode:



$$V_{D\,total} = V_{D_{DC}} + v_{D_{AC}}.$$

$$I_{D\,total} = I_{D_{DC}} + I_{D_{AC}}.$$

$$\rightarrow \quad I_D = I_s\, e^{V_D/V_t}.$$

$$I_{D.DC} = I_s .\, e^{V_{DDC}/V_t} \quad \text{—— ①}$$

$$I_{D\,total} = I_s\, e^{\frac{V_{D\,total}}{V_t}}$$

$$= I_s .\, e^{\frac{V_{DDC} + v_{DAC}}{v_t}}$$

$$\therefore I_{D\,total} = I_s .\, e^{\frac{V_{DDC}}{V_t}} .\, e^{\frac{V_{DAC}}{V_t}} = I_{D_{DC}} .\, e^{\frac{V_{DAC}}{V_t}}$$

$$\Downarrow$$

$$e^{\frac{V_{DAC}}{V_t}} = \left[1 + \frac{V_{D_{AC}}}{V_t} \right]$$

$$\therefore I_{D\,total} = I_{D.DC} \left[1 + \frac{V_{DAC}}{V_t} \right] \Longleftarrow$$

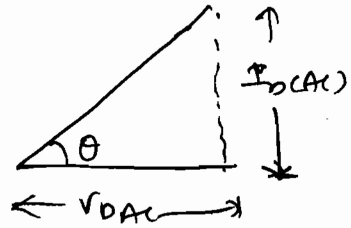
$$\therefore \cancel{I_{D}}_{DC} + I_{DAC} = \cancel{I_{D}}_{DC} + I_{D.DC} . \frac{V_{DAC}}{V_t}$$

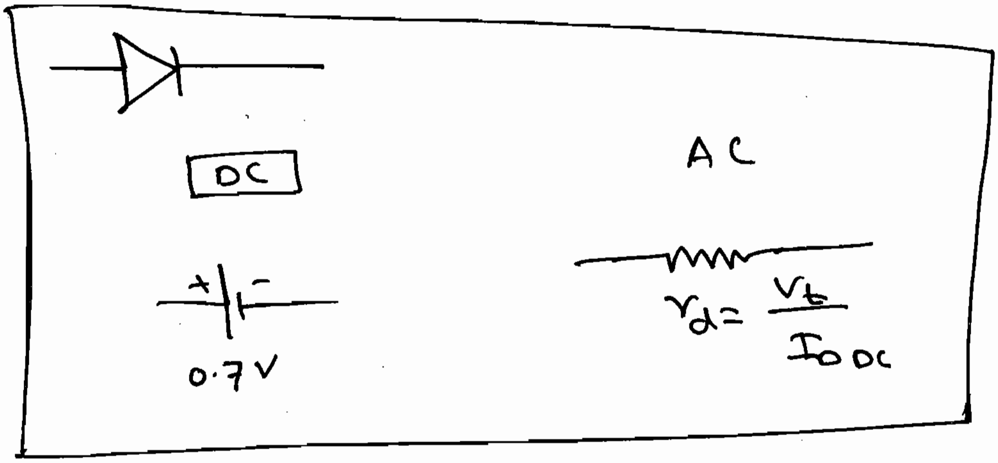
$$I_{D_{AC}} = I_{D_{DC}} \cdot \frac{V_{D_{AC}}}{V_t}.$$

→ Diode Resistance,

$$(r_d) = \frac{V_{D_{AC}}}{I_{D_{AC}}} = \frac{V_t}{I_{D_{DC}}} = \text{const.}$$

$$\therefore \; r_d = \frac{V_t}{I_D}.$$





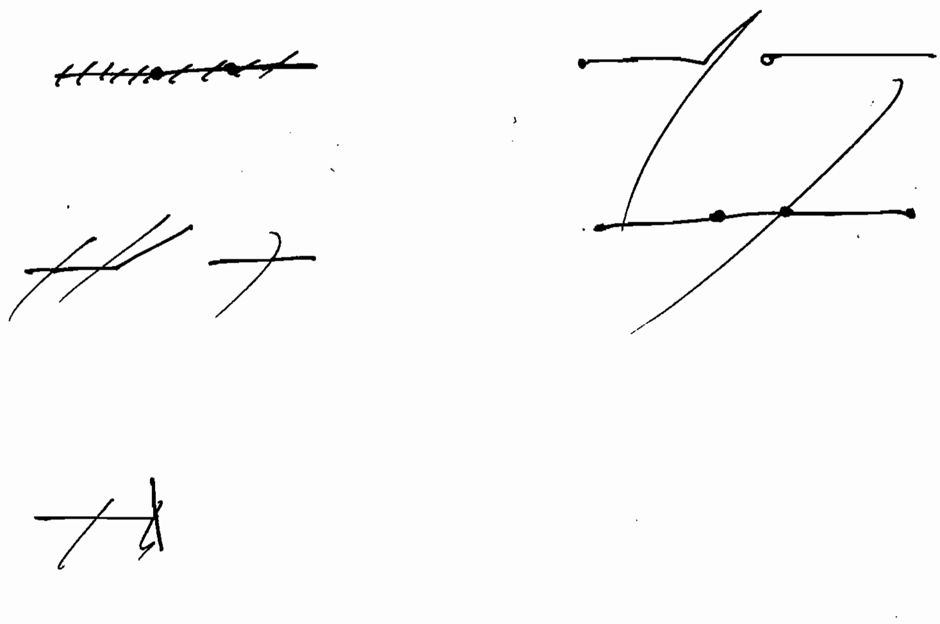
Diode work as a linear Device.

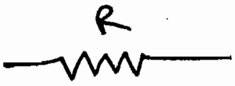
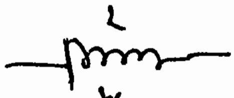
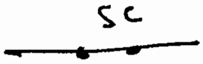
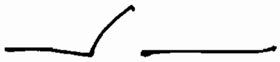
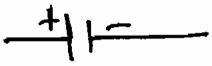
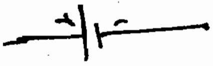
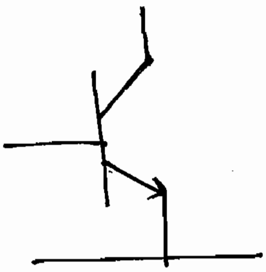
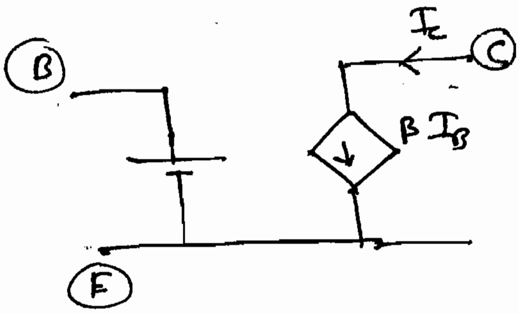
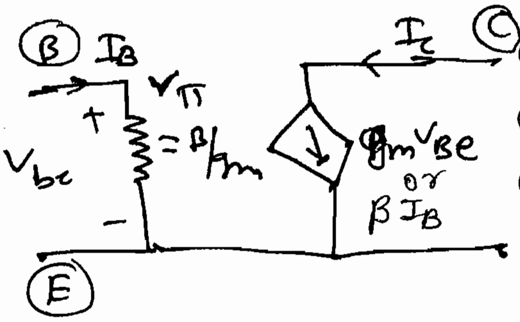
~~DC (ω = 0)~~ ~~AC (ω = high).~~

1. Resistor
R Ω

2. Inductor
$|\omega L|$

3. Capacitor
C
$\frac{1}{\omega C}$



	DC ($\omega = 0$)	AC (ω = high).
1. Resistor 		
2. Inductor  ωL	SC 	 o.c.
3. Capacitor  $1/\omega C$	o.c. 	s.c. 
4. Diode (small signal) 	 0.7v	$r_d = \frac{V_t}{I_{DC}}$ 
5. BJT 		

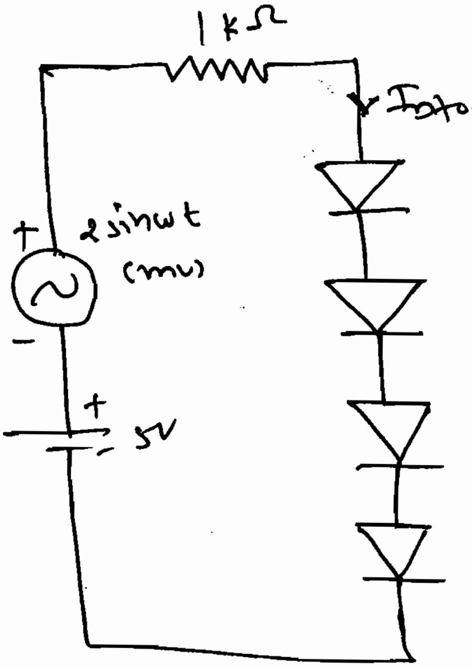
$$I_c = g_m v_{be}, \quad v_{be} = I_B r_\pi$$

$$\therefore \quad r_\pi = \frac{v_{be}}{I_B} = \frac{I_c}{g_m \times I_B}$$

$$I_c = \beta I_B$$

$$\therefore \quad \boxed{r_\pi = \beta / g_m}$$

☆ Find the total Diode current if $V_t = 25mV$ and forward drop $V_D = 0.7$ volts.

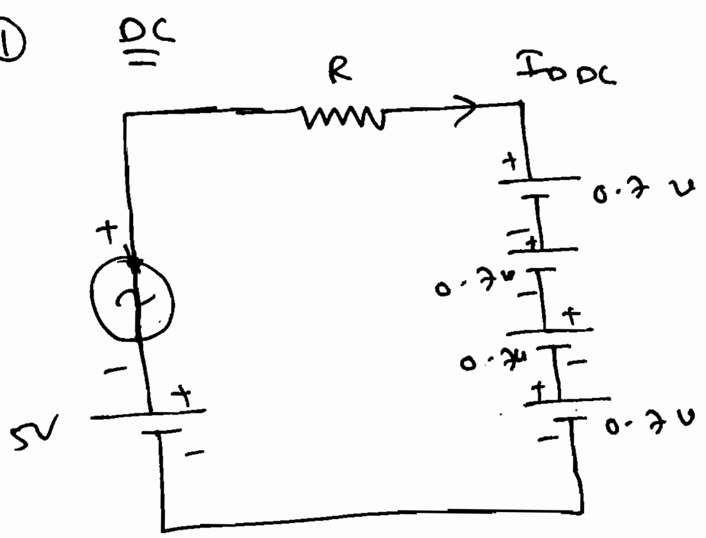


NOTE:

(i) Diode is 2 terminal/ nonlinear / passive device.

(ii) BJT is 3 terminal/ nonlinear / active device.

① DC

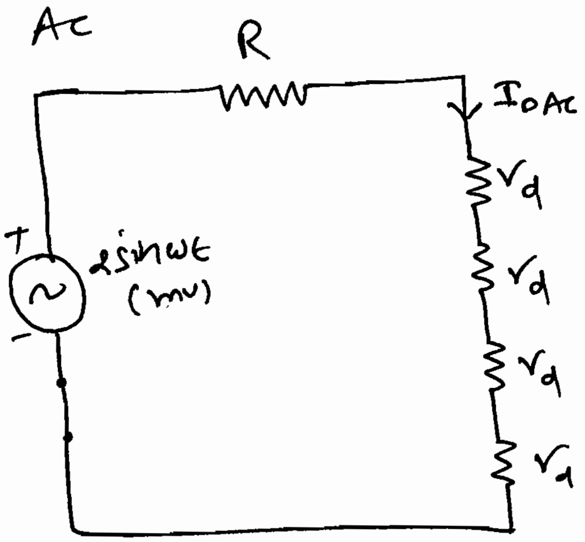


$$I_{D DC} = \frac{5 - (4 \times 0.7)}{1k}$$

$$I_{D DC} = 5 - 2.8 \text{ mA}$$

$$I_{D DC} = 2.2 \text{ mA}.$$

② AC



$$r_d = \frac{V_t}{I_{D DC}}$$

$$r_d = \frac{25}{2.2} = 11.36\ \Omega.$$

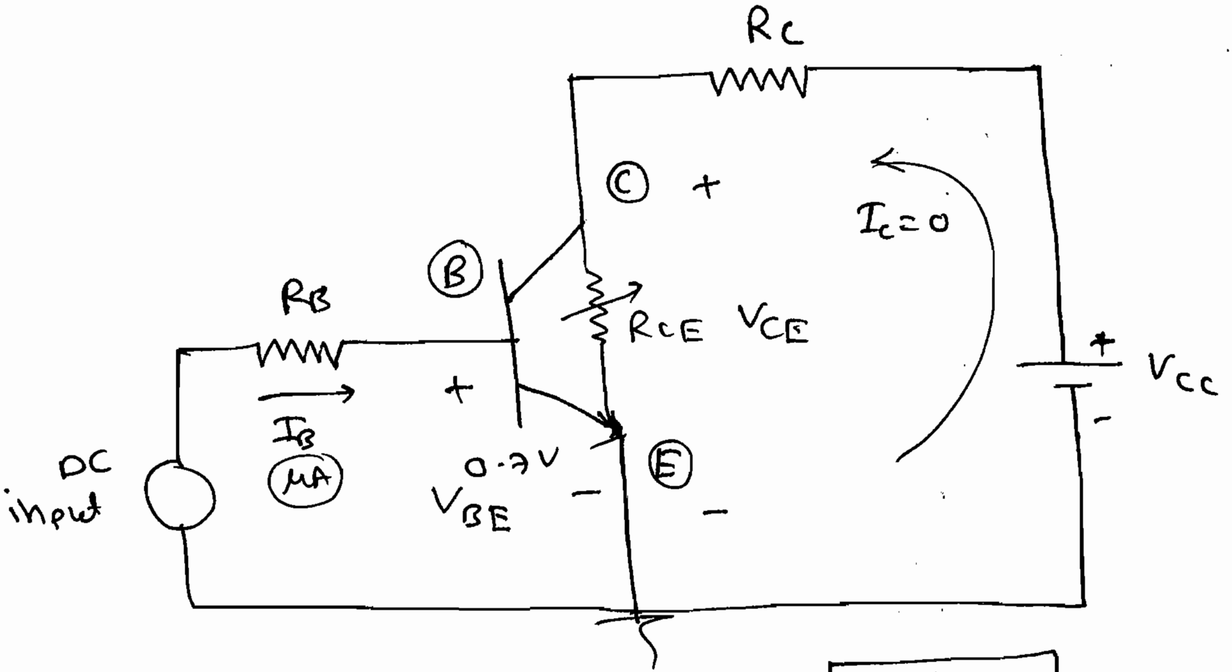
$$I_{D AC} = \frac{2 \sin\omega t}{4(11.36) + 1k}$$

$$I_{D AC} = 1.913 \sin\omega t \text{ mA}.$$

$$I_{D AC} = 1.913 \sin\omega t \text{ mA}.$$

$$\boxed{I_{D total} = I_{D DC} + I_{D AC} = 2.2 + 1.913 \sin\omega t \text{ mA}.}$$

☆ BJT and its region of operation:



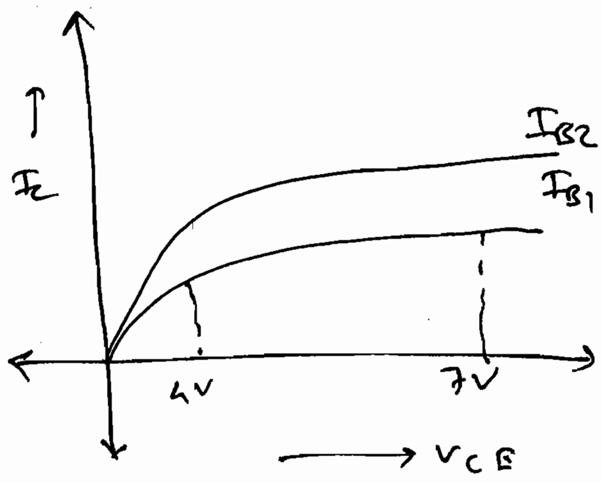
$$\boxed{\beta I_B = I_C} \quad mA$$

→ I_C is control by I_B form input side.

$$\therefore \quad I_C = \frac{V_{CC}}{R_C + R_{CE}} = 0 \quad \text{cut off}$$

V_{CC}	I_C	V_{CE}	$R_{CE} = \frac{V_{CE}}{I_C}$
5	1m	4V	4K
6	1m	5V	5K
7	1m	6V	6K
8	1m	7V	7K

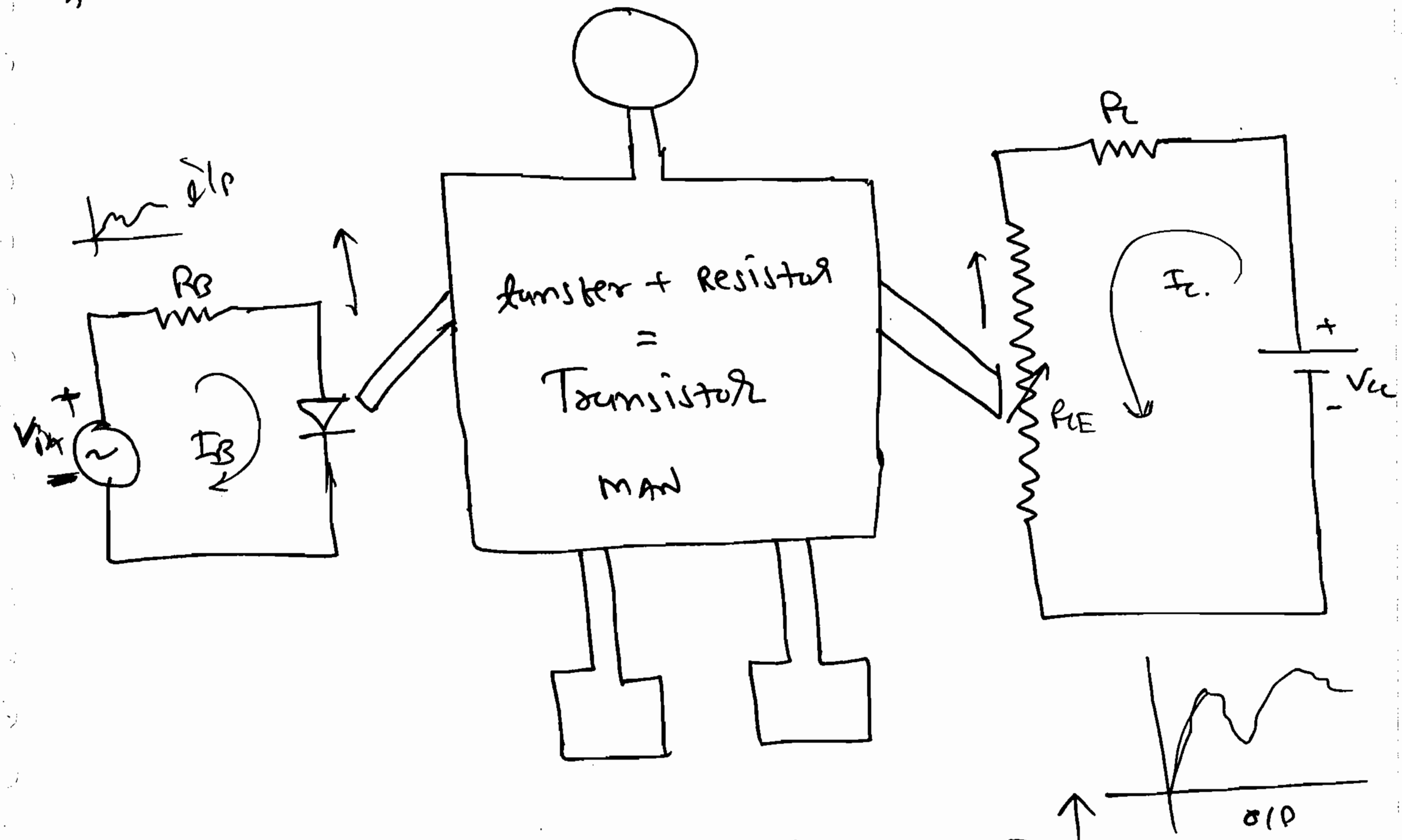
$R_C = 1k$



→ I_C is only change when I_B or R_B will change.

→ So, BJT is current control current source device.

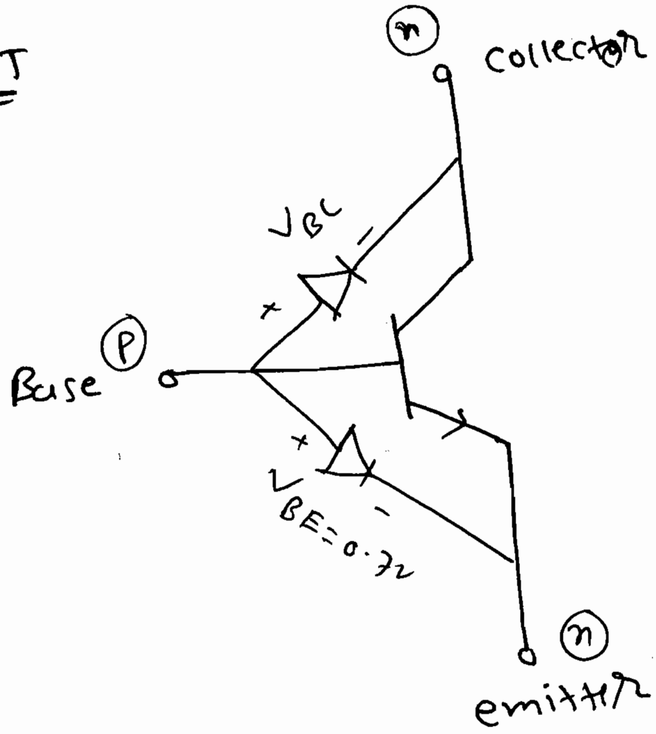
*



If $I_B \uparrow \Rightarrow R_{CE} \downarrow \Rightarrow I_C \uparrow$

If $I_B \downarrow \Rightarrow R_{CE} \uparrow \Rightarrow I_C \downarrow$.

BJT

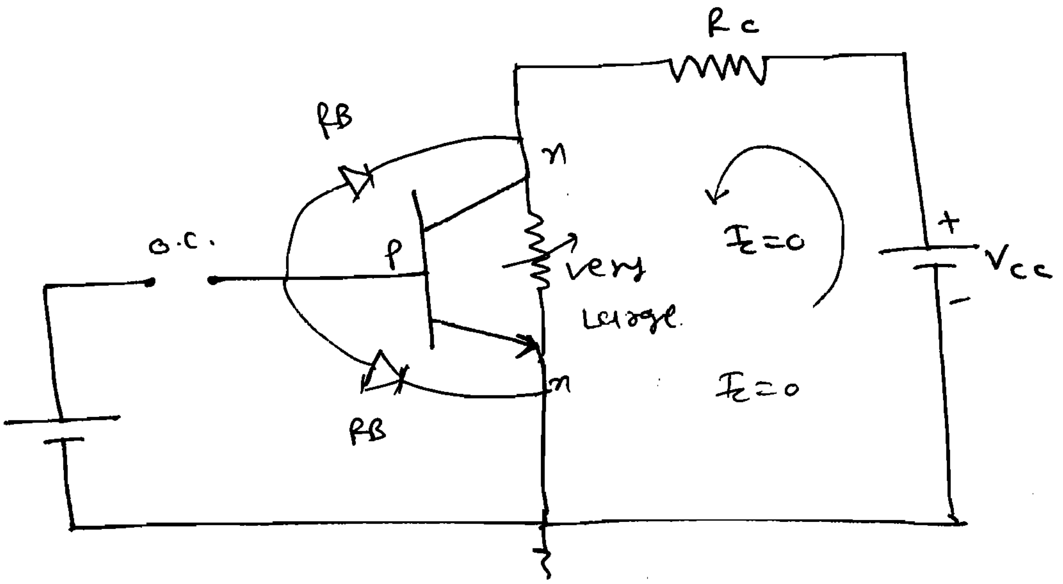


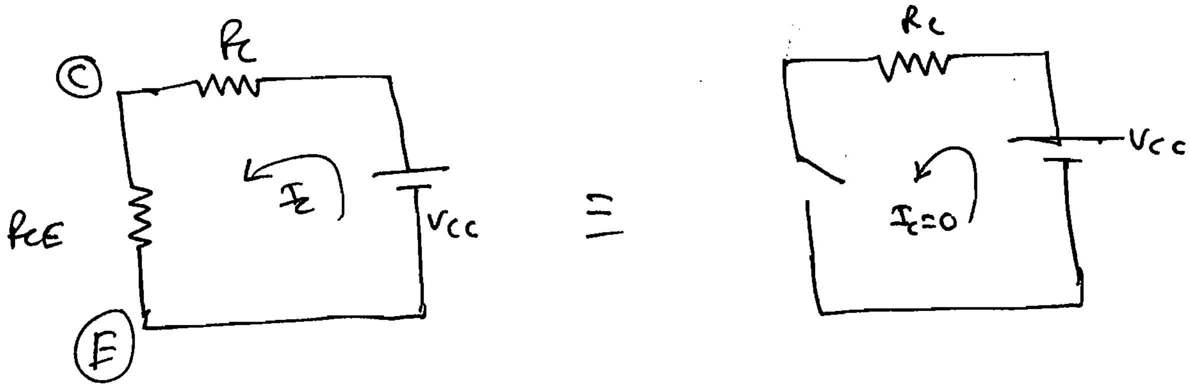
BJT is a controlled OFF ~~switch~~ switch which is controlled from input side.

*

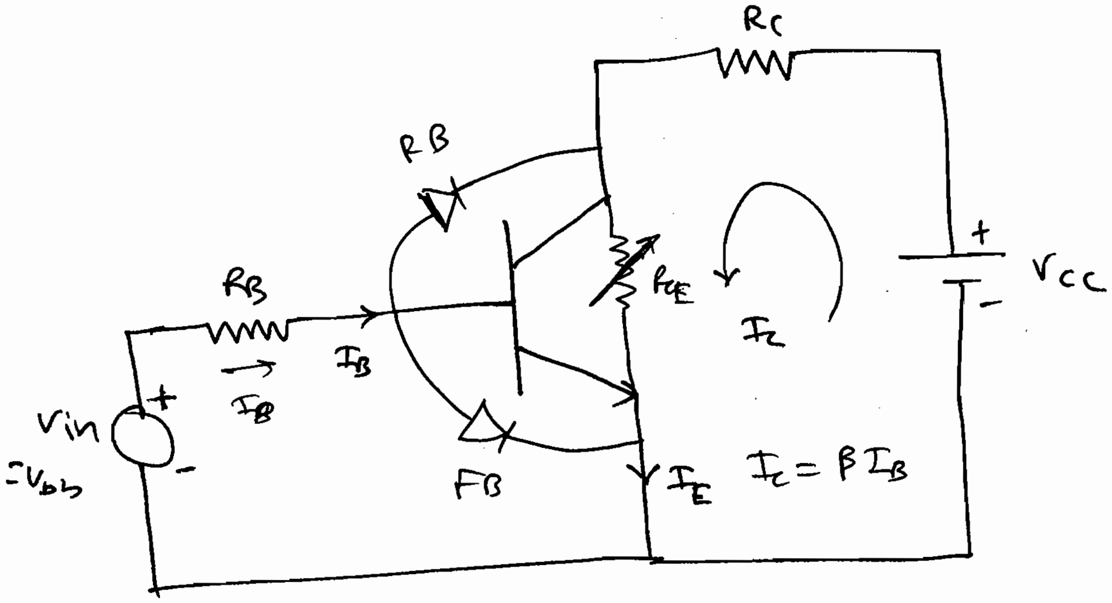
	Emitter-Base Jun.	Collector-Base junction
1. Cut off	$V_{BE} < 0.6\,V$ RB	$V_{BE} < 0.6V$ RB
2. Inverse Active	$V_{BE} < 0.6\,V$ RB	$V_{BC} > 0.6V$ FB
3. Active	$V_{BE} \geq 0.6\,V$ FB	$V_{BC} < 0.6V$ RB
4. Saturation	$V_{BE} \geq 0.6\,V$ FB	$V_{BC} \geq 0.6V$ FB

1. Cut-off:

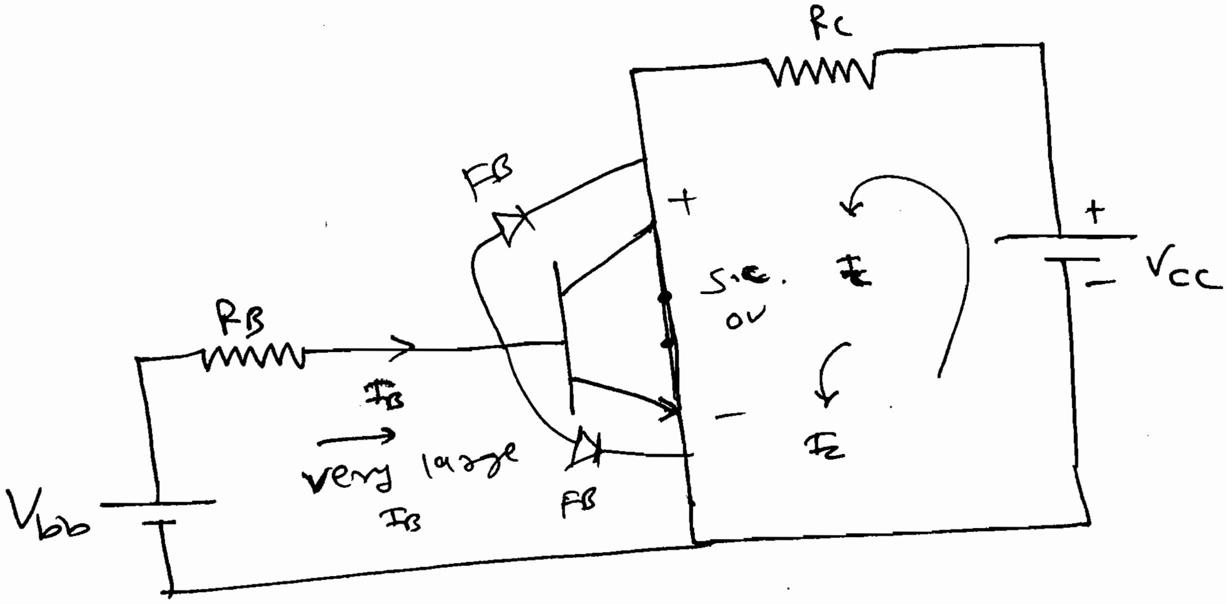




2. Active



3. Saturation:



$|I_B| > |I_B|_{active}$.

$\therefore |I_B| > \left|\frac{I_C}{\beta_{active}}\right|$

$\therefore \beta_{active} > \left|\frac{I_C}{I_B}\right|$.

$\therefore \boxed{\beta_{forced} < \beta_{active}.}$

I_B is very large

$\Downarrow$

No effect on I_C.

Resistance $\Rightarrow$ BJT

∞ — Cut off

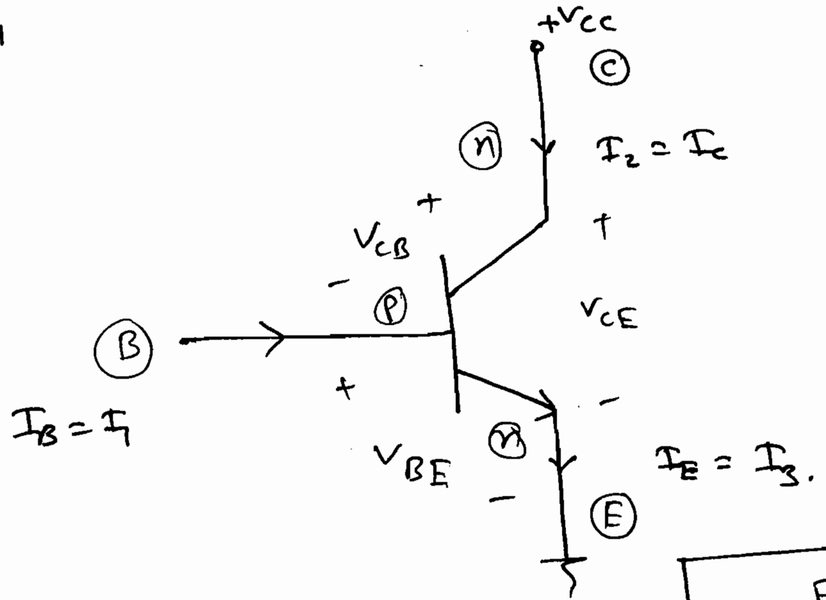
0 — saturation

Active region for Amp.

Cutoff region for Switches.

* Solving BJT problem:

① NPN



For npn

$V_{BE} \rightarrow$ Forward

Active $CB \rightarrow$ Reverse

it is

$V_{CE} > 0.2\,V$

KCL, $I_1 + I_2 = I_3$.

$\therefore \quad I_E = I_B + I_C$.

KVL, $-V_{BE} - V_{CB} + V_{CE} = 0$.

$\therefore \quad V_{CE} = V_{BE} + V_{CB}$.

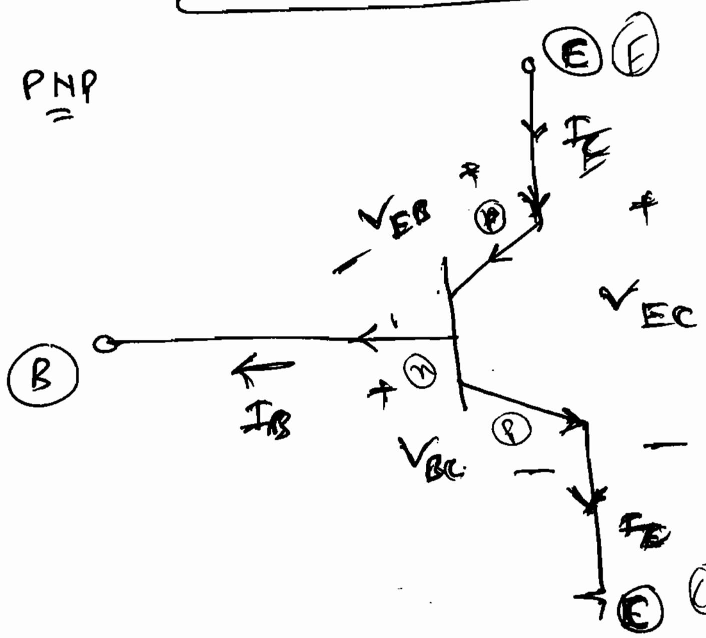
PNP,

$CB \Rightarrow$ Forward.

$BE \Rightarrow$ Reverse.

$V_{EC} > 0.2$.

② PNP

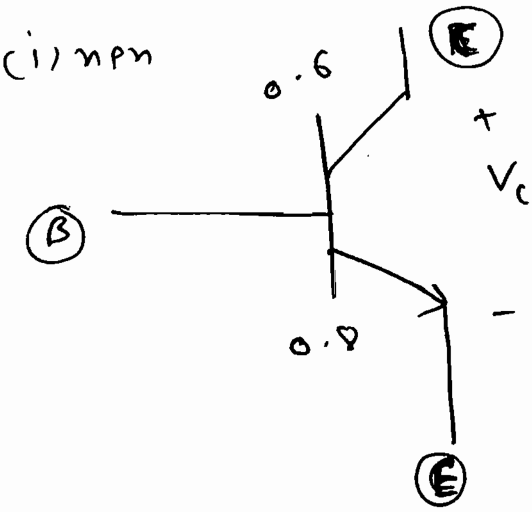


KVL,

$\boxed{V_{BC} + V_{EB} - V_{EC} = 0}$

① Active Condition:

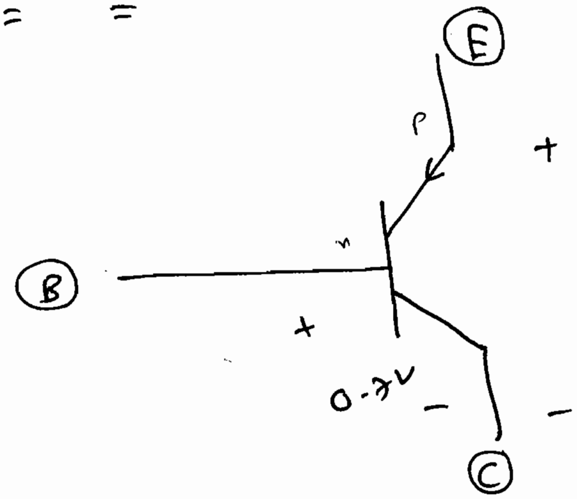
(i) npn



$V_{CE} > 0.2\,V \Leftarrow$ Prove

$I_C = \beta I_B$ assume

(ii) pnp:



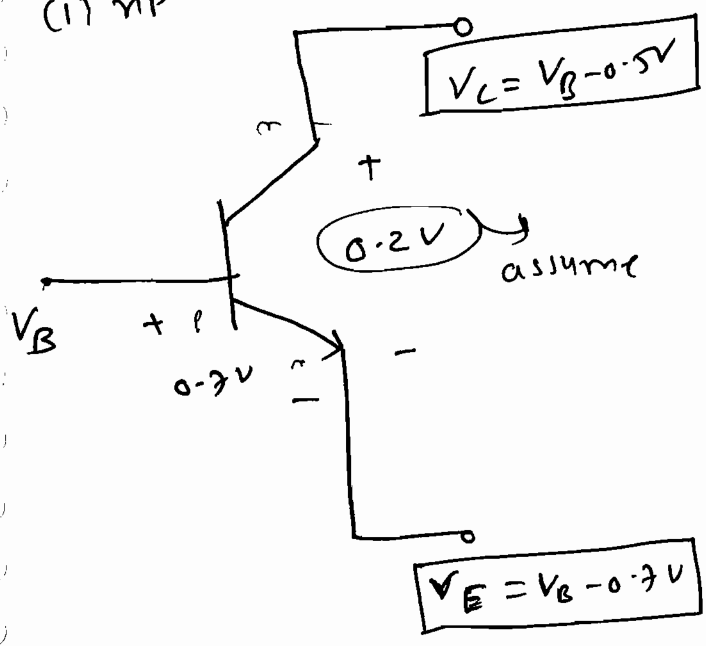
$V_{EC} > 0.2 \Leftarrow$ prove

$I_C = \beta I_B$ assume

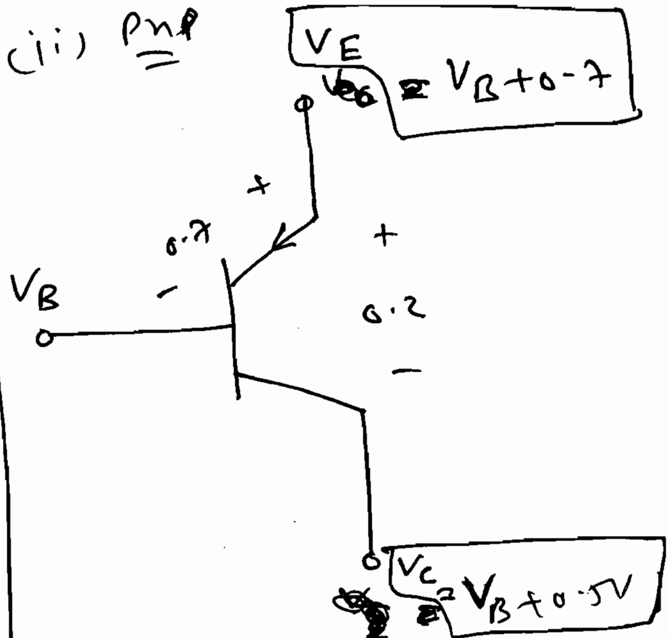
② Saturation Condition:

(i) npn

$V_C = V_B - 0.7 + 0.2V$

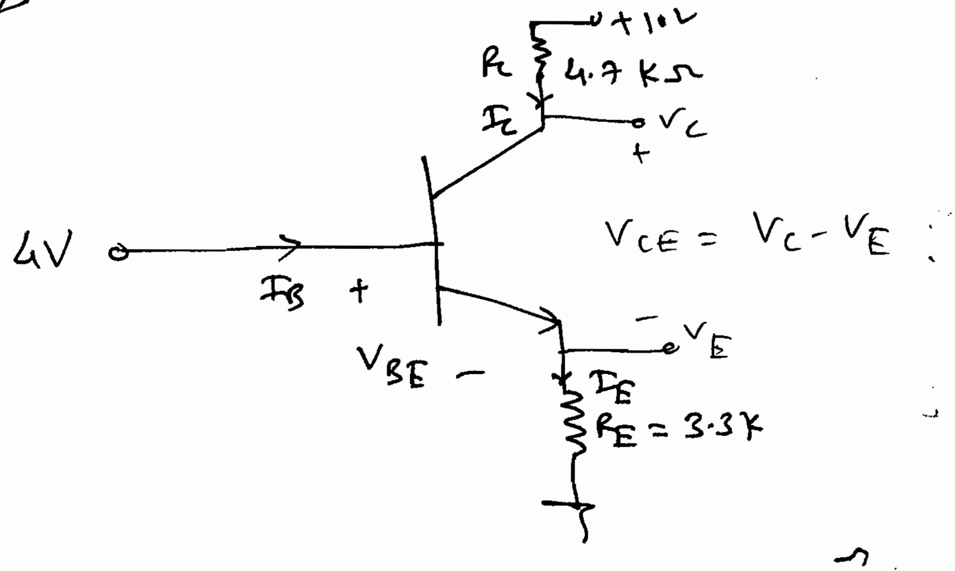


(ii) pnp



Prove $\beta_{forced} < \beta_{active}$

Ex-1 Find All node Voltage and Branch current. take $\beta = 100$.



Ans:-

$$V_E = 4 - V_{BE}$$

$$\therefore V_E = 4 - 0.7$$

$$\boxed{V_E = 3.3V}$$

$$\therefore I_E = \frac{V_E}{R_E}.$$

$$\therefore I_E = \frac{3.3}{3.3K}$$

$$\boxed{I_E = 1\ mA}$$

$$\therefore I_E = I_C + I_B.$$

$$\therefore I_E = \beta I_B + I_B.$$

$$\therefore I_E = (\beta+1)\ I_B$$

$$I_C = \beta I_B.$$

$$\therefore \frac{I_C}{I_E} = \frac{\beta}{\beta+1}.$$

$$I_c = \frac{\beta}{\beta+1} \cdot I_E$$

$$\therefore I_c = \frac{100}{101} \cdot 1mA$$

$$\therefore \boxed{I_c = 0.9909 \text{ mA}}$$

$$\rightarrow V_c = 10 - I_c R_c$$

$$= 10 - (0.9909m) \times (4.7 \times 1000)$$

$$\therefore \boxed{V_c = 5.346 V}$$

$$\therefore V_{CE} = V_c - V_E \quad (\because npn)$$

$$\therefore V_{CE} = 5.346 - 3.3$$

$$\boxed{V_{CE} = 2.046} > 0$$

So, transistor is in active condition.

<u>Procedure:</u>

V_E

↓

I_E

↓

I_c

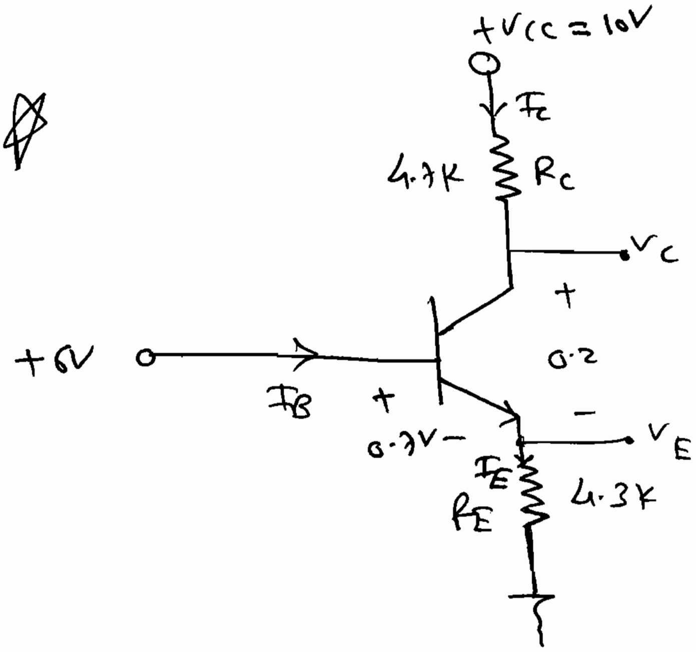
↓

V_c

↓

Check: V_{CE}.

Ex-2



Ans:

$$V_E = 6 - 0.7V$$

$$\boxed{V_E = 5.3V}$$

$$\therefore I_E = \frac{V_E}{R_E} = \frac{5.3}{4.3}.$$

$$\therefore \boxed{I_E = 1.2325 \text{ mA}}$$

$$\therefore I_C = \frac{\beta}{\beta+1} I_E$$

$$\therefore I_C = \frac{100}{101} \times 1.2325 \text{ mA}$$

$$\therefore \boxed{I_C = 1.2203 \text{ mA}}$$

$$\therefore V_C = 10V - I_C R_C$$

$$= 10 - (1.2203m \times 4.7K).$$

$$\therefore \boxed{V_C = 4.26 V}$$

$$\therefore V_{CE} = V_C - V_E = 4.26 - 5.3 < 0.2$$

$\therefore$ ~~V_{CEA}~~

So, transistor is not in active.

Now, Let, $V_{CE} = 0.2$. and we will find β_{forced}.

$\therefore V_E = 6 - V_{BE}$

$\therefore V_E = 6 - 0.7 = 5.3V.$

$\therefore \boxed{V_E = 5.3V.}$

$V_{CE} = 0.2$

$\therefore V_C - V_E = 0.2.$

$\therefore \boxed{V_C = 5.5V.}$

$\therefore I_C = \dfrac{V_{CC} - V_C}{R_C}.$

$\therefore I_C = \dfrac{10 - 5.5}{4.7}$

$\therefore \boxed{I_C = 0.957mA}.$

$I_E = \dfrac{V_E}{R_E}$

$I_E = 1.2325.$

$\therefore I_B = I_E - I_C$

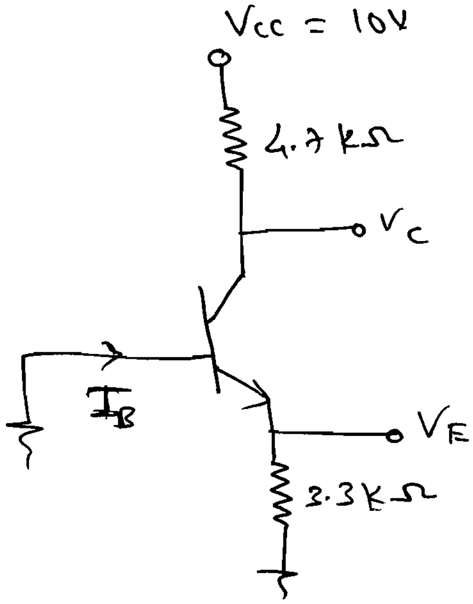
$\boxed{I_B = 0.275 \cdot mA}$

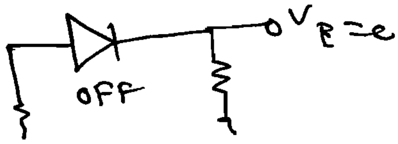
$\therefore \beta_{forced} = \dfrac{I_C}{I_B}$

$\boxed{\beta_{forced} = 3.473 < \beta_{active}.}$

So, transistor is in saturation region.

Ex 3 $\cancel{\phi}$





Ans:

$V_E = 0$

$I_E = 0$

$I_c = 0.$

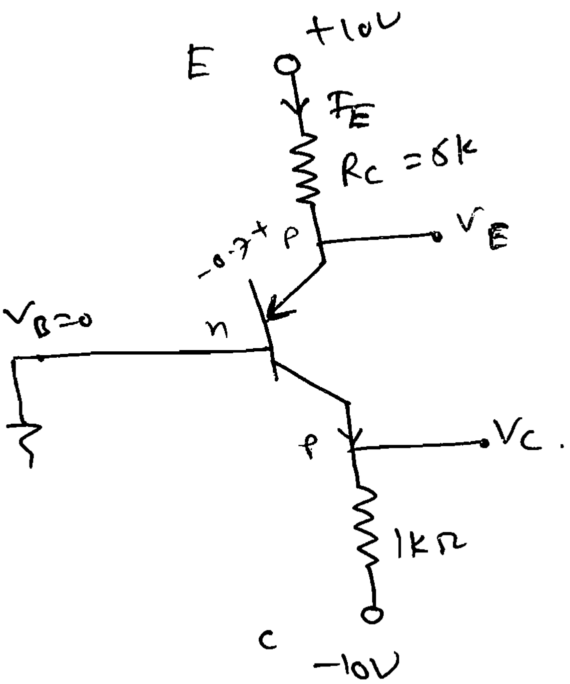
$\therefore \quad V_c = V_{cc} - I_c R_c$

$\therefore \quad V_c = V_{cc} = 10V$

$\therefore \quad \boxed{V_c = 10V.}$

So, transistor is in cutoff.

Ex 4 $\cancel{\phi}$



$\therefore V_E = V_B + V_{BE}.$

$\therefore V_E = 0 + 0.7\,V$

$\boxed{V_E = 0.7V}$

$\therefore I_E = \dfrac{10 - 0.7}{5k}$

$\therefore \boxed{I_E = 1.86\,mA}$

$\therefore I_C = \dfrac{\beta}{\beta+1} \times I_E$

$\therefore I_C = \dfrac{100}{101} \times 1.86$

$\therefore \boxed{I_C = 1.84\,mA.}$

$\therefore V_C = I_C R_C - 10V.$

$V_C = (1.84) - 10V.$

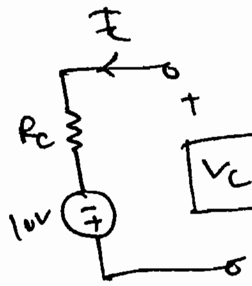
$\therefore \boxed{V_C = -8.16}$

$V_{EC} = V_E - V_C$

$\therefore V_{EC} = 0.7 - (-8.6)$

$\therefore V_{EC} = 8.76 > 0.2V$

so, in active region.



$\boxed{V_C = I_C R_C - 10.}$

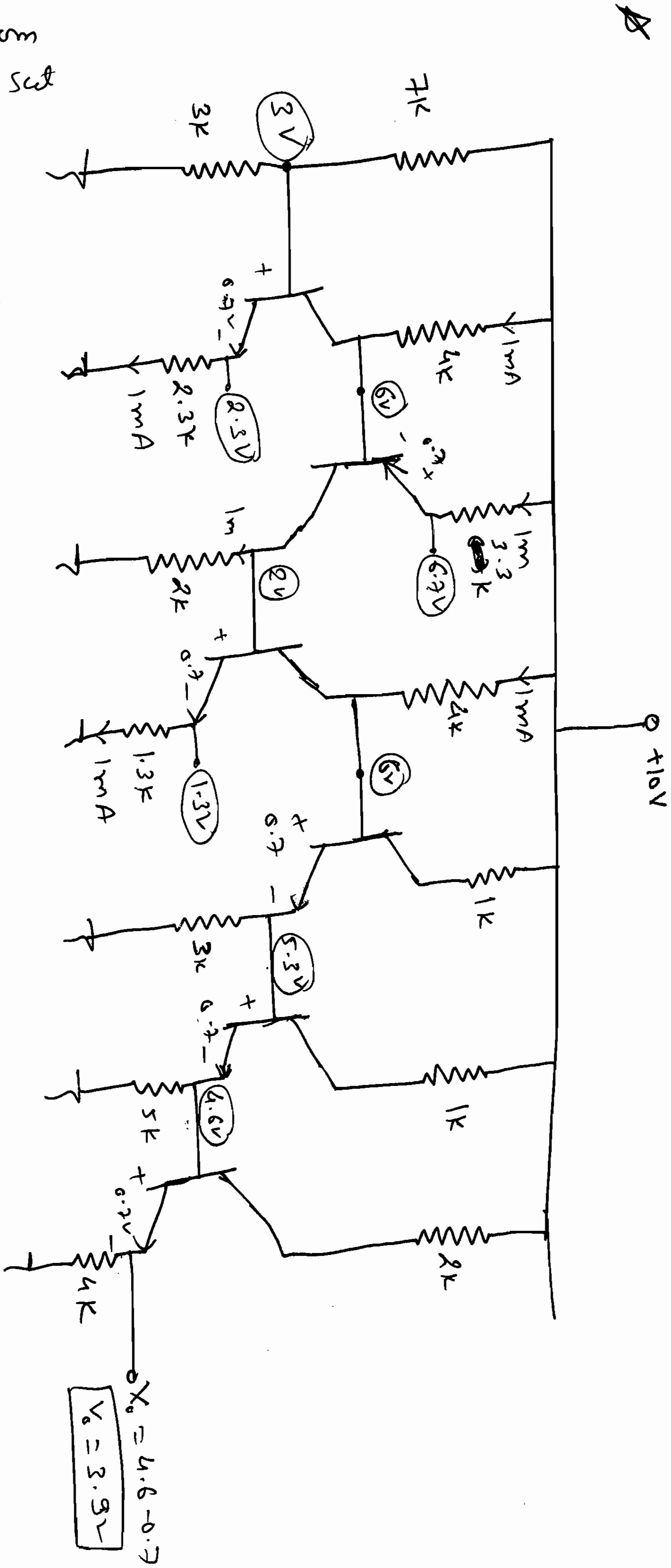
* To make BJT from sat active to sat following two ways can be applicable:

(*) $\dfrac{I_C \downarrow \; R_C \uparrow}{\uparrow I_B \; V_{bb}\uparrow} = \beta_{forced} < \beta_{active}$

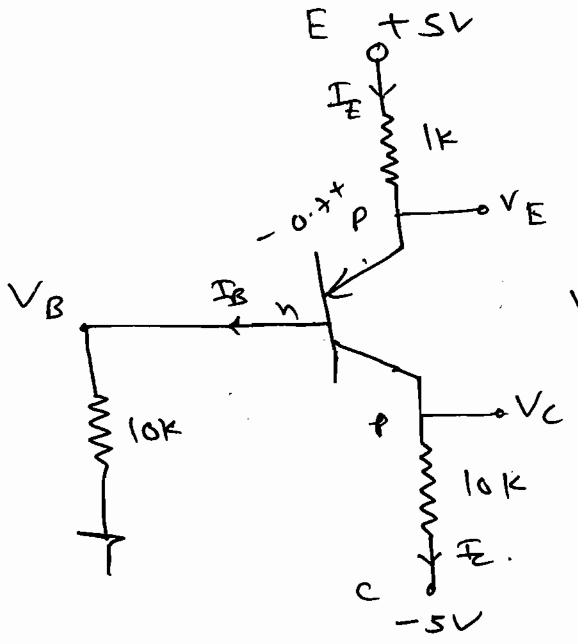
→ (i) I_c should be ~~increase~~ decrease and it can be achive by increasing value of R_c:

$R_c >>$ Large.

(ii) By increasing V_{bb} I_B can be increased which in turn reduce the β_{forced}.



Ex-4 Calculate the All node voltages and branch current $\beta = 100$ and it is in saturation.



$V_{EC} = 0.2V$

$\boxed{V_E = V_B + 0.7}$

$V_C = V_E - V_{EC}$

$\therefore V_C = V_B + 0.7 - 0.2$

$\boxed{V_C = V_B + 0.5}$

$\rightarrow \quad I_E = I_B + I_C.$

$$\therefore \frac{5 - V_E}{1k} = \frac{V_B}{10k} + \frac{V_C + 5V}{10k}.$$

$$\therefore 10(5 - V_B - 0.7) = V_B + V_B + 5 + 0.5$$

$$50 - 10V_B - 7 = 2V_B + 5.5$$

$$\therefore 12V_B = 37.5$$

$$\therefore \boxed{V_B = 3.125\ V}$$

$$\therefore I_B = V_B / R_B = \frac{3.125}{10k} = 0.3125\,mA$$

$$\therefore I_C = \frac{3.125 + 5 + 0.5}{10} = 0.86\,mA.$$

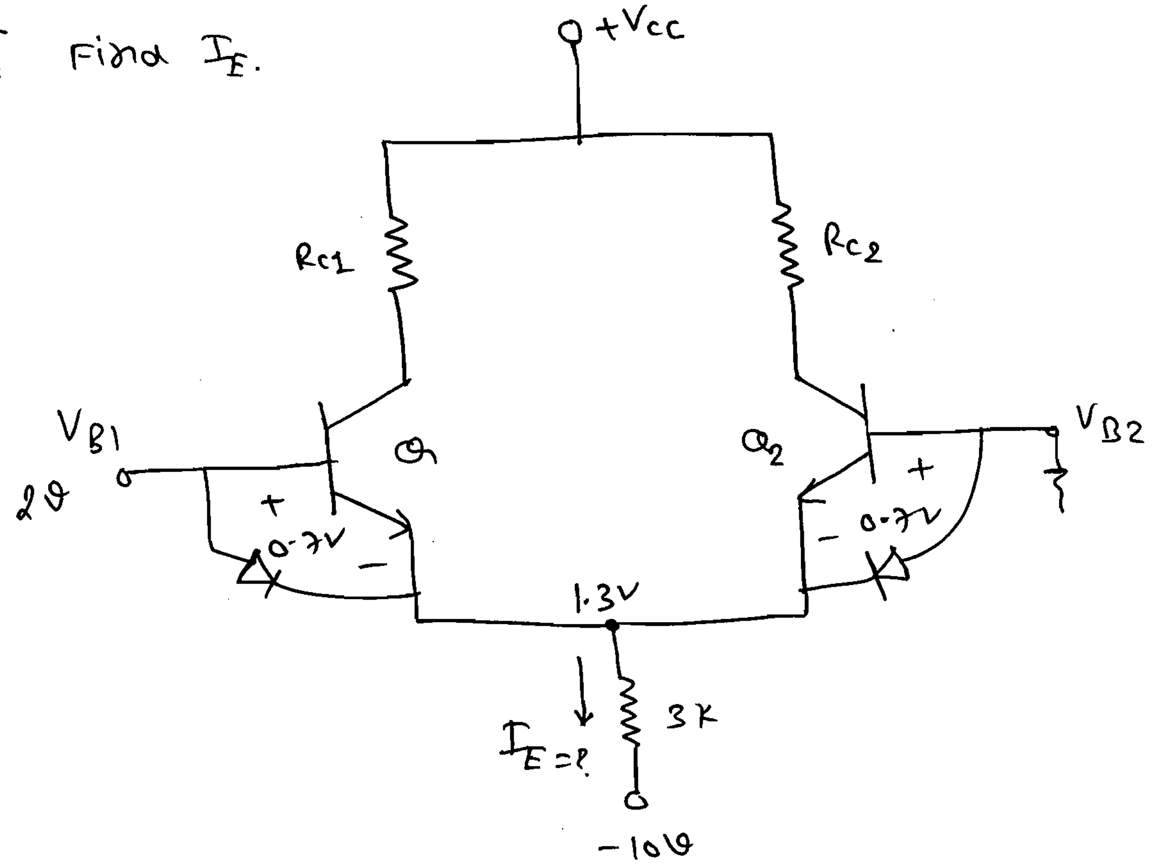
$$\therefore \beta_{forced} = \frac{0.86}{0.3125} = 2.752 < \beta_{active}.$$

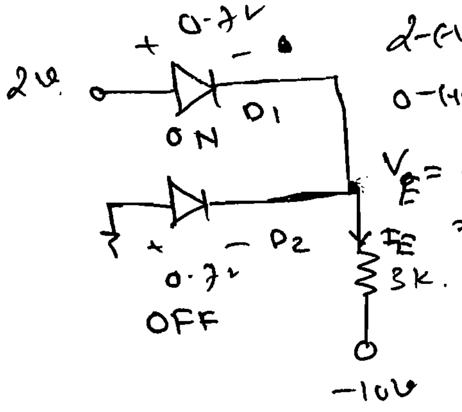
So, it is in sat.

$I_E = I_C + I_B = 1.1725\ mA$

$\boxed{I_E = 1.1725\,mA}$

Ex-5 Find I_E.





2-(-10)=12

0-(-10)=10

$V_E = 2 - 0.7$

$= 1.3V$

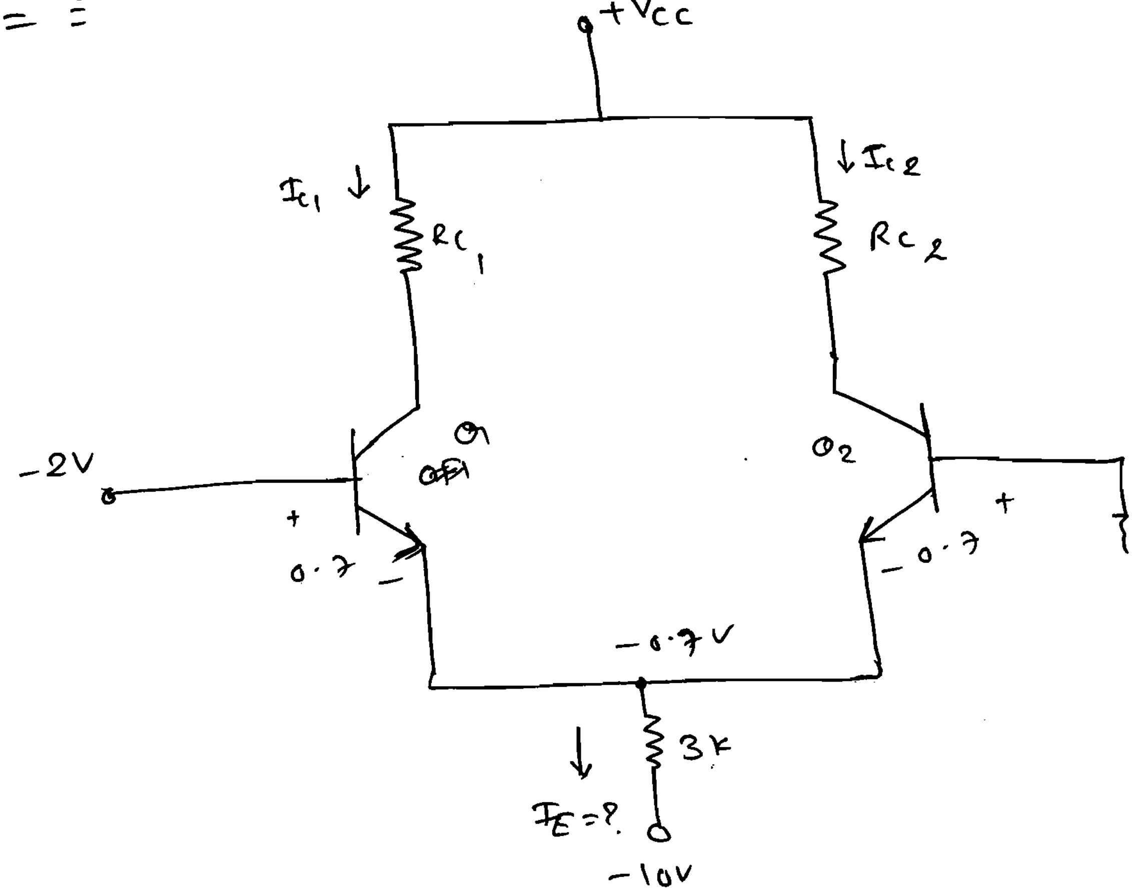
D_1 is on because it experience ~~less~~ more potential difference.

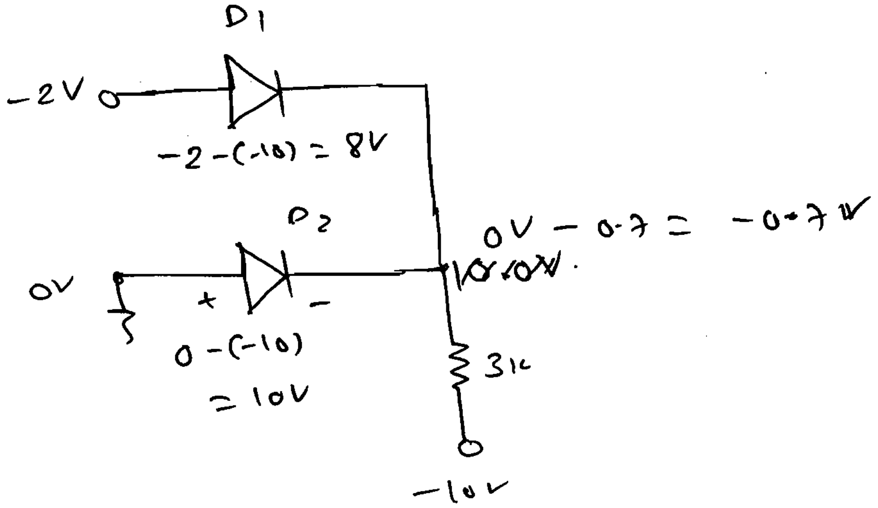
$$\therefore I_E = \frac{1.3 - (-10)}{3K}$$

$$\boxed{I_E = 3.76mA}$$

→ Diode in BJT can be on by either Voltage divider or giving + negative supply.

Ex 2

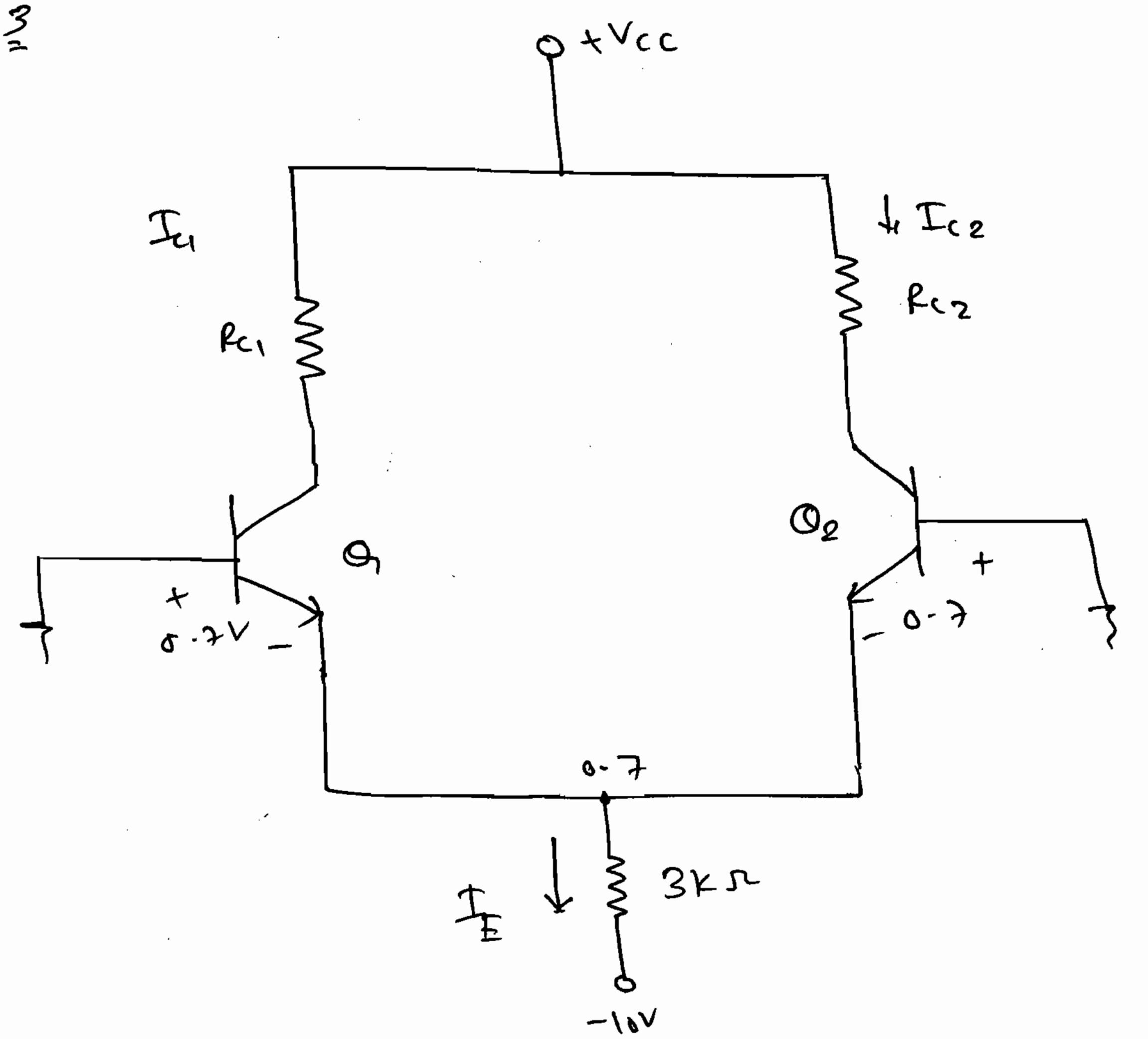


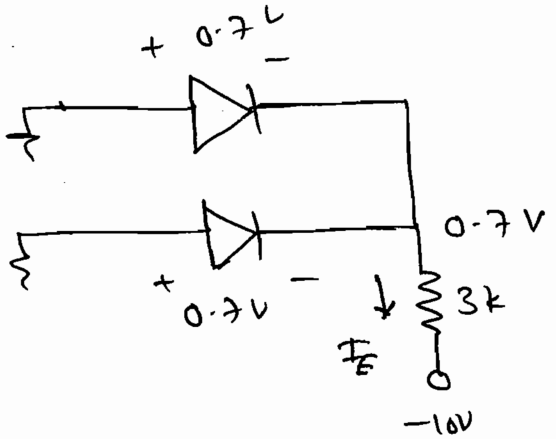


$$\therefore \quad I_E = \frac{-0.7 - (-10)}{3K}$$

$$\therefore \quad \boxed{I_E = 3.1mA.}$$

Ex 3





$$\therefore \quad I_E = \frac{0.7-(-10)}{3k} = \frac{10.7}{3k} = 3.567\,mA$$

$$I_{C1} = I_{C2} = I_C$$

$$\therefore \quad 2I_C = I_E$$

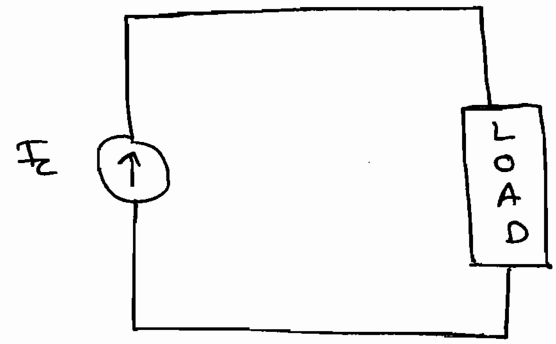
$$\therefore \quad I_{C1} = I_{C2} = I_E/2$$

$$\therefore \quad \boxed{I_{C1} = I_{C2} = 1.78\,mA}$$

Biasing a BJT:

→ The purpose of biasing is to switch on the BJT to work in active region such that the DC collector current remain constant independent of β, Temp. and load variations.

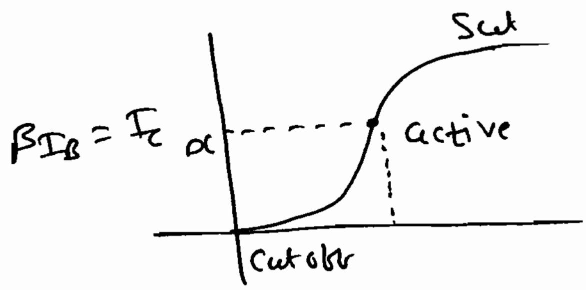
→



$$I_c \neq f(\beta, \text{temp}, \text{Load})$$

$$\therefore \boxed{I_c \neq f(\beta, V_{be}, V_{ce})}$$

① β (with R_E).



if β change the $I_c = \beta I_B$ changes.

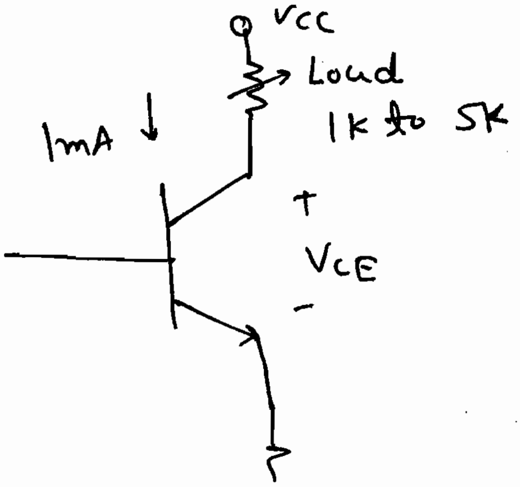
② Temperature:

→ $V_{BE} = -2.5\,m/°C$

→ If temp. changes ⇒ V_{BE} changes. this will change I_B and will turn in change the I_c.

③ Load Variations:

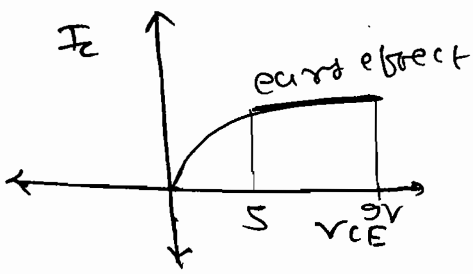
→



$$V_{CE} = V_C - V_E.$$

$$\therefore V_{CE} = V_{CC} - I_C R_C - V_E$$

$$\therefore I_C = \frac{V_{CC} - V_{CE} - V_E}{R_C}$$



if R_C changes

⇓

V_{CE} changes

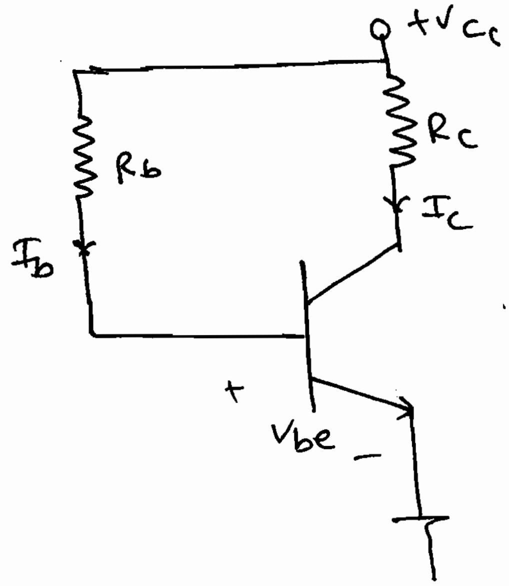
⇓

I_C will change.

→ In order to rid this problem we should make constant current source.

① Fixed Bias / Fixed Base bias:

→



→ $$I_B = \frac{V_{CC} - V_{BE}}{R_b}.$$

$V_{BE} \simeq$ const.
$R_b \simeq$ const.

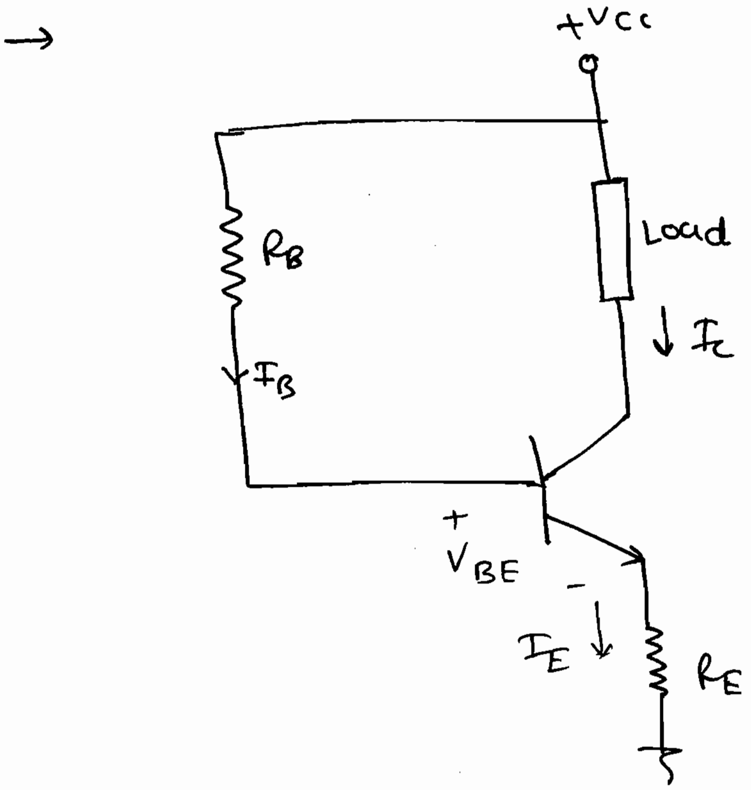
$\therefore \; I_B =$ const.

$$\therefore \; I_C = \beta I_b = \beta\left[\frac{V_{CC} - V_{BE}}{R_B}\right].$$

→ β Changes from 50 to 250 for the different specimens of the given transistor type. any ckt which depend of a particular value of β is a bad ckt.

→

Without R_E	With R_E
$I_C = \beta I_B$	$I_C = \beta I_B.$
$I_B = K$ = const.	$I_C = K$ = const
$I_C = \beta I_B.$	$\therefore \; I_B = I_C/K.$



$$\rightarrow \quad V_{CC} = I_B R_B + V_{BE} + I_E R_E$$

But, $\quad I_E = (\beta+1) I_B.$

$$\rightarrow I_B = I_E / \beta+1.$$

$$\therefore \quad V_{CC} - V_{BE} = \left(\frac{R_B}{\beta+1} + R_E \right) I_E.$$

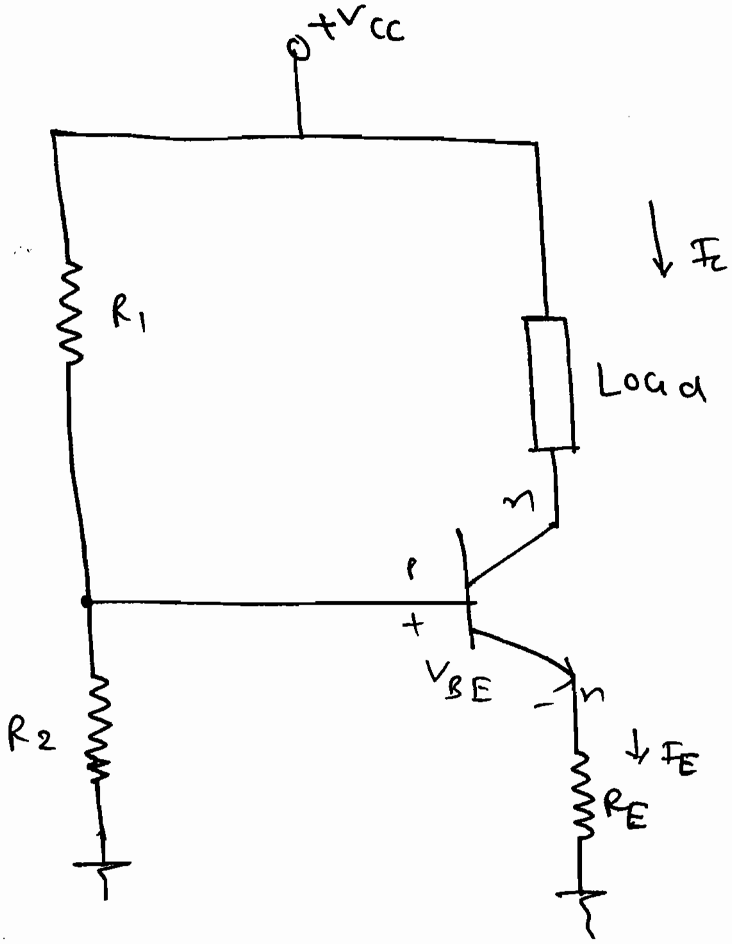
$$\therefore \quad I_E = \frac{V_{CC} - V_{BE}}{R_E + \frac{R_B}{\beta+1}}.$$

Now, choose $\boxed{R_E \gg \frac{R_B}{\beta+1}}$

$$\therefore \quad I_E \simeq I_{DC} = \frac{V_{CC} - V_{BE}}{R_E}.$$

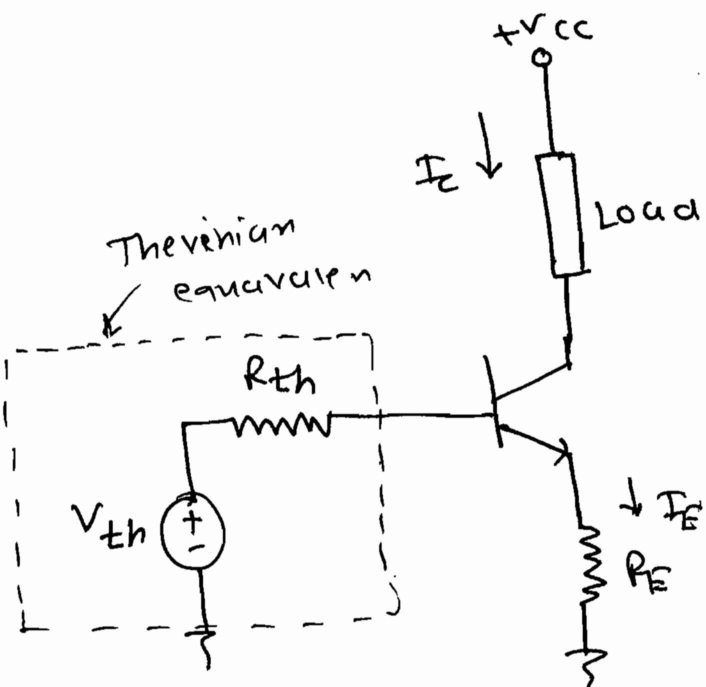
② Voltage divider bias (or) Self bias (or) Universal bias.

⇛



→

|||



(neglacting I_B).

$I_B \simeq 0A$

$$V_{th} = \frac{V_{cc} R_2}{R_1 + R_2}$$

$$R_{th} = \frac{R_1 . R_2}{R_1 + R_2} = R_1 \| R_2$$

$$\rightarrow \quad V_{th} - V_{BE} - I_B R_B - I_E R_E = 0.$$

$$\therefore \quad I_B = \frac{I_E}{\beta+1}.$$

$$\therefore \quad I_E \left[\frac{R_B}{\beta+1} + R_E \right] = V_{th} - V_{BE}.$$

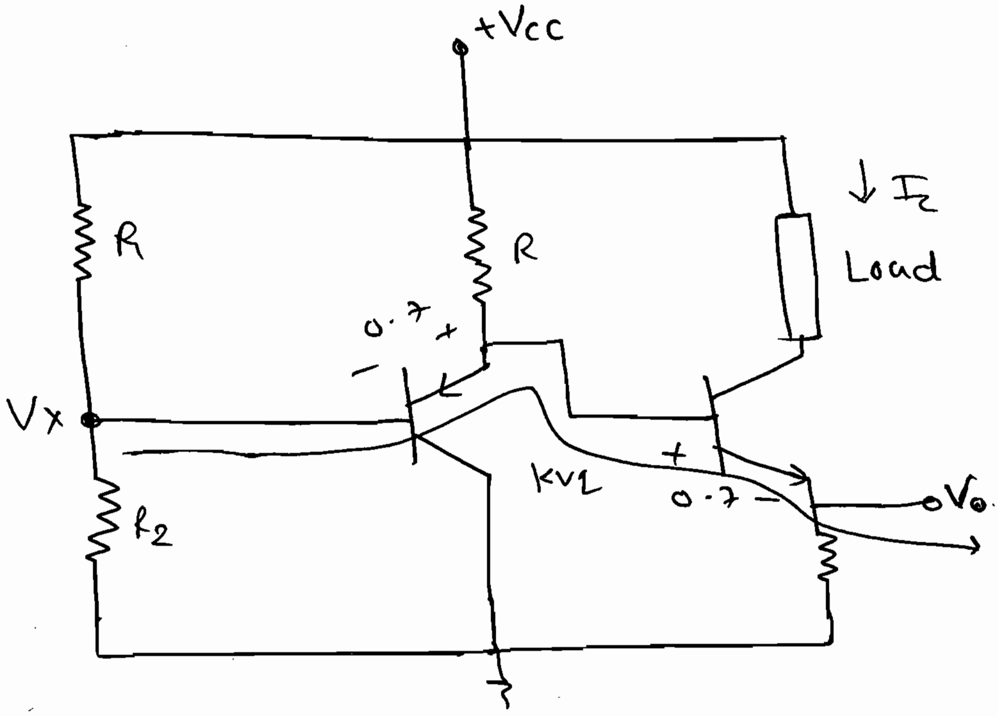
$$\therefore \quad \boxed{I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_B}{\beta+1}} \simeq I_{CQ}}$$

$$R_E >> \frac{R_{th}}{\beta+1}.$$

$$\therefore \quad R_E >> \left(\frac{R_1 \cdot R_2}{R_1 + R_2} \right) \times \frac{1}{\beta+1}.$$

$$\therefore \quad \boxed{I_{CQ} = \frac{\frac{V_{CC} R_2}{R_1 + R_2} - V_{BE}}{R_E}}$$

Ex-1



$$\rightarrow \quad V_x = \frac{V_{cc} R_2}{R_1 + R_2}.$$

$$\therefore \quad V_x + 0.7 - 0.7 - V_o = 0.$$

$$\therefore \quad V_x = V_o = V_E$$

$$\therefore \quad \boxed{V_E = V_o = \frac{V_{cc} R_2}{R_1 + R_2} \, v}$$

$$\therefore \quad I_c \simeq I_E = \frac{V_E}{R_E}.$$

$$\therefore \quad I_c = \frac{\frac{V_{cc} R_2}{R_1 + R_2}}{R_E}$$

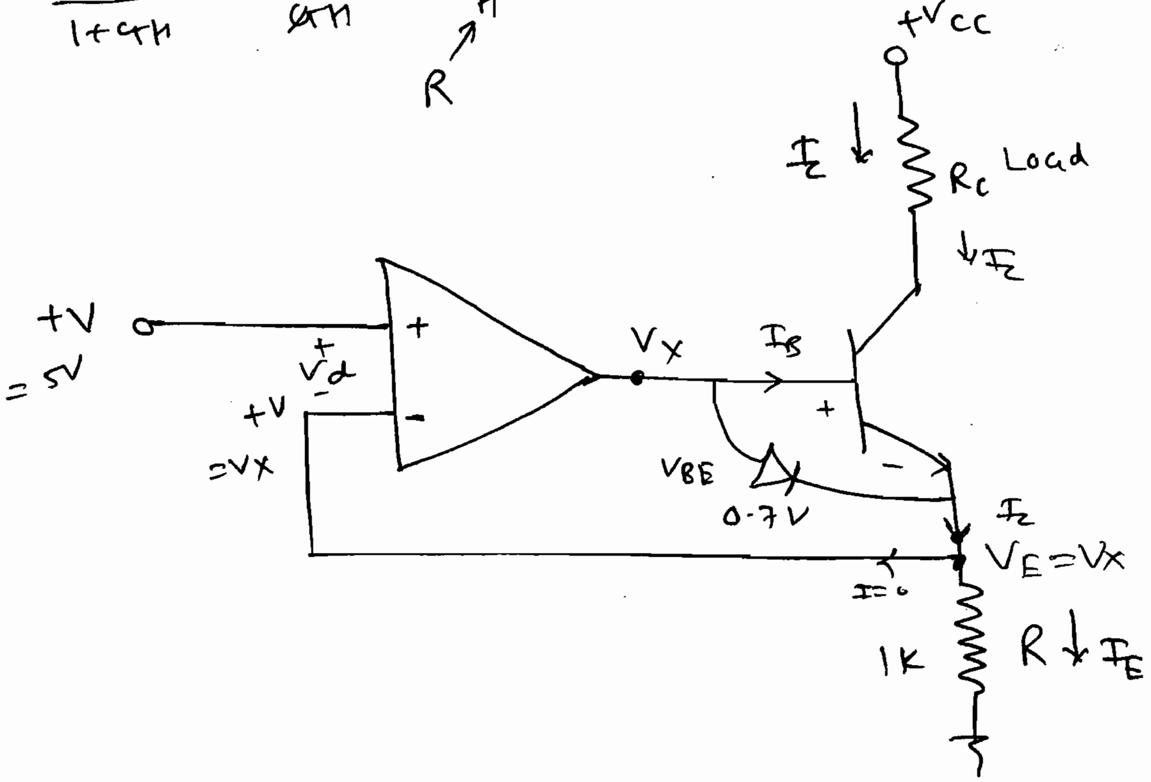
$$\therefore \quad \boxed{I_c = \frac{V_{cc} R_2}{(R_1 + R_2) R_E} = V/R.}$$

NOTE: Designing a current source with Op-Amp in −ve feedback will totally eliminate the problem of drift.

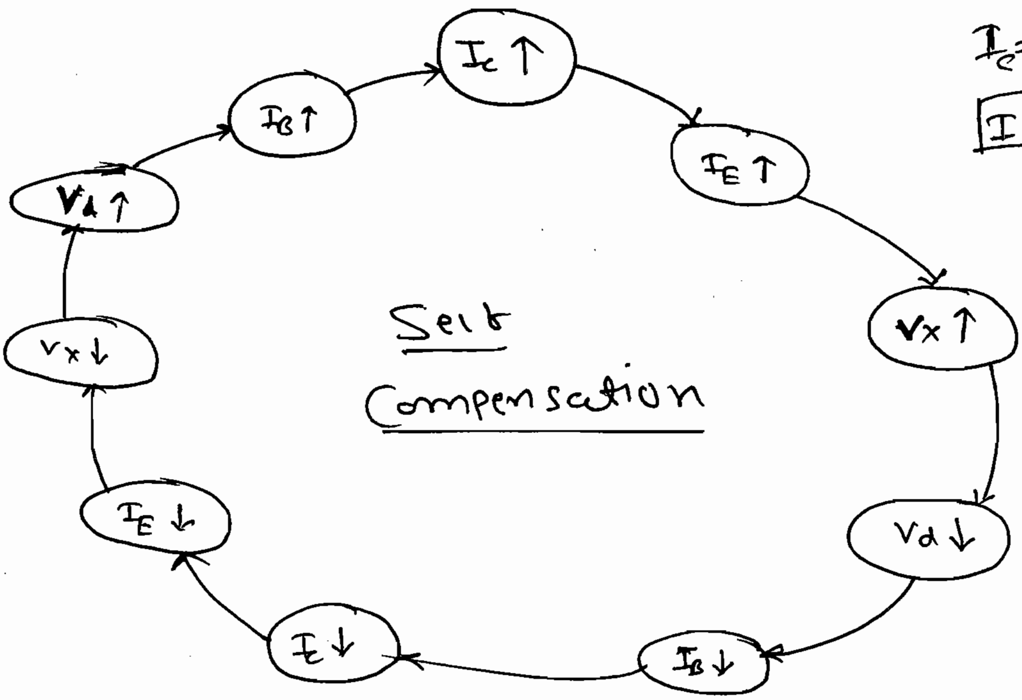
*

$$\frac{G}{1+GH} = \frac{G}{GH} = \frac{1}{H}$$

$H \rightarrow R$



⇒

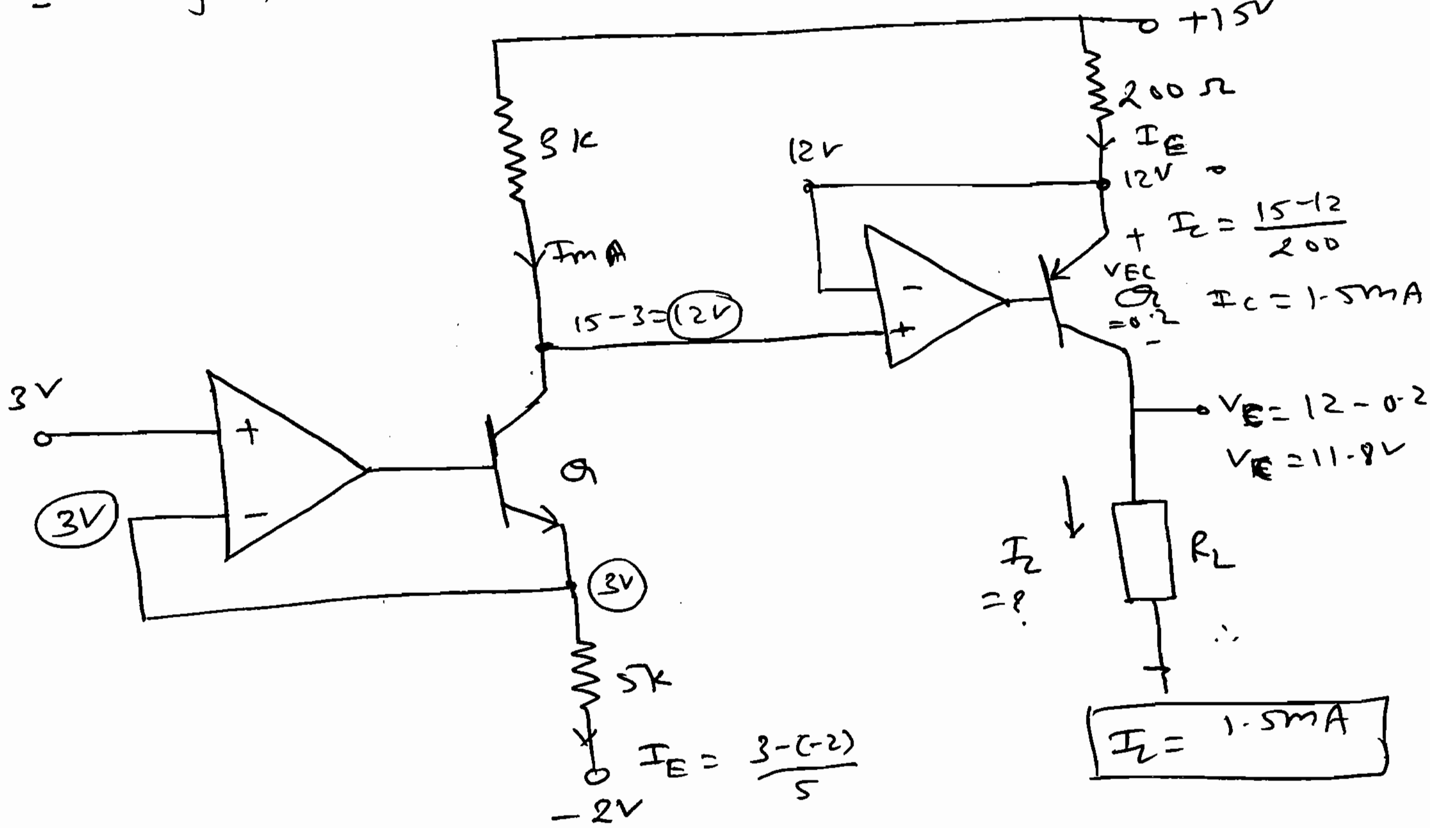


$I_c = 5/1k$

$\boxed{I_c = 5mA}$

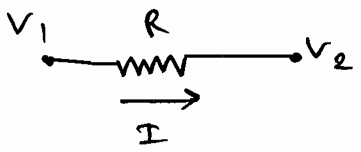
→ Temp. changes but all parameters stable which is because of −ve feed back mechanism provided by non-inverting OP-Amp.

Ex-1 Voltage programmable current source with grounded load.



$I_E = 1mA$

*** NOTE:**



$\Rightarrow \boxed{I = \frac{V_1 - V_2}{R}}$, $\boxed{V_2 = V_1 - IR}$

→ find the minimum value of R_L for the BJT to be in sat. with $V_{EC} = 0.2$.

$\therefore V_E = 12V$

$V_{EC} = 0.2V$

$\therefore V_E - V_C = 0.2$

$\therefore V_C = 12 - 0.2 = 11.8V.$

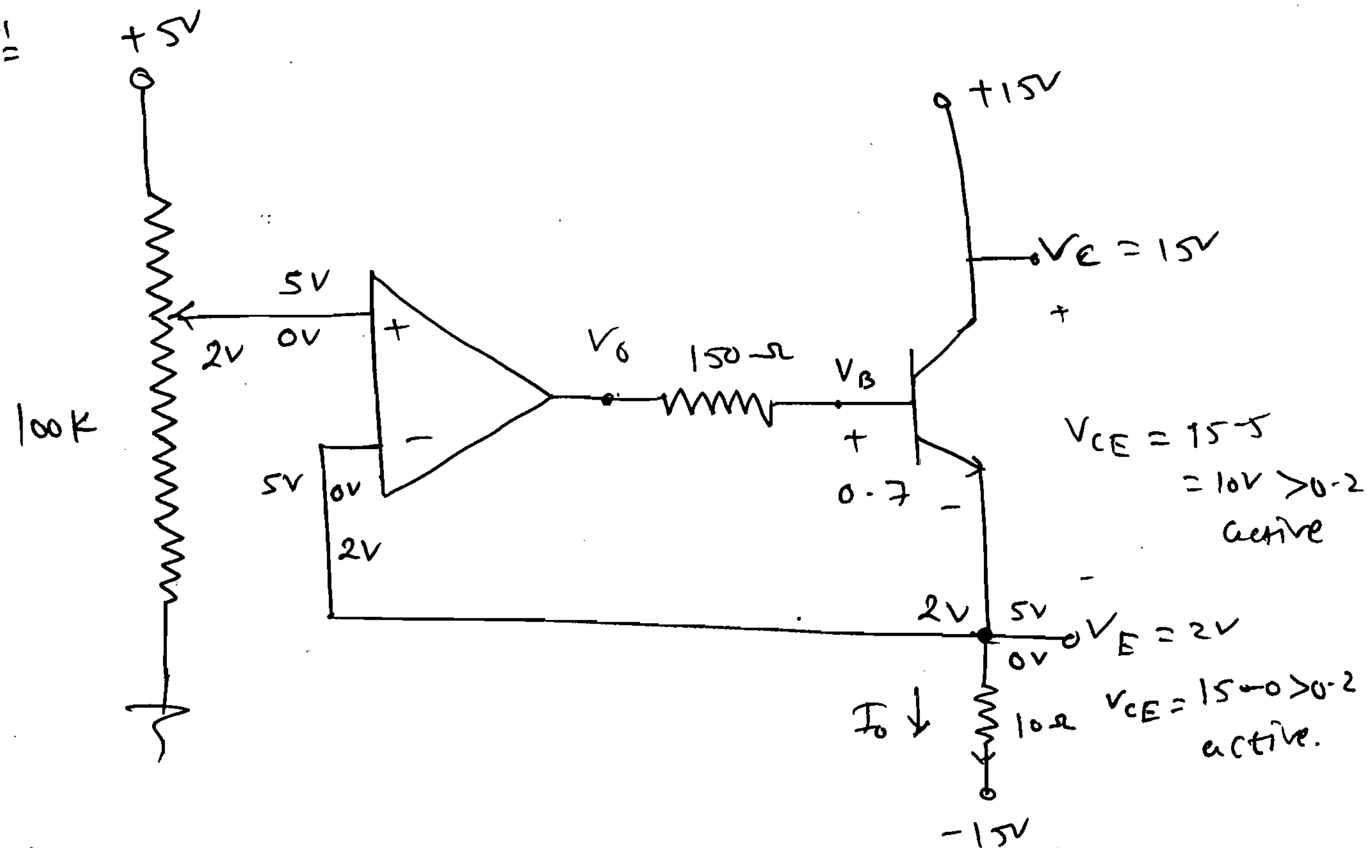
$\therefore R_L = V_C / I_C$

$\therefore R_{L\,min} = \frac{11.8}{1.5m}$

$\therefore \boxed{R_{L\,min} = 786\ \Omega}$

(HM)

Ex-1



Find

(a) Check the region of operation.

(b) If Vin = 2V then find V_o & I_o.

Ans: (a) Possible value of Vin is +5 & 0.

for Both the value transistor is active region as shown in ckt.

(b) Now, Vin = 2V

$V_E = 2V$.

$\therefore I_o = \dfrac{2-(-15)}{10}$

$\therefore \boxed{I_o = 1.7\text{ A}}$

$\therefore V_B - 0.7 = 2V$

$\therefore \boxed{V_B = 2.7V}$

$\therefore \dfrac{V_o - V_B}{150} = I_B$

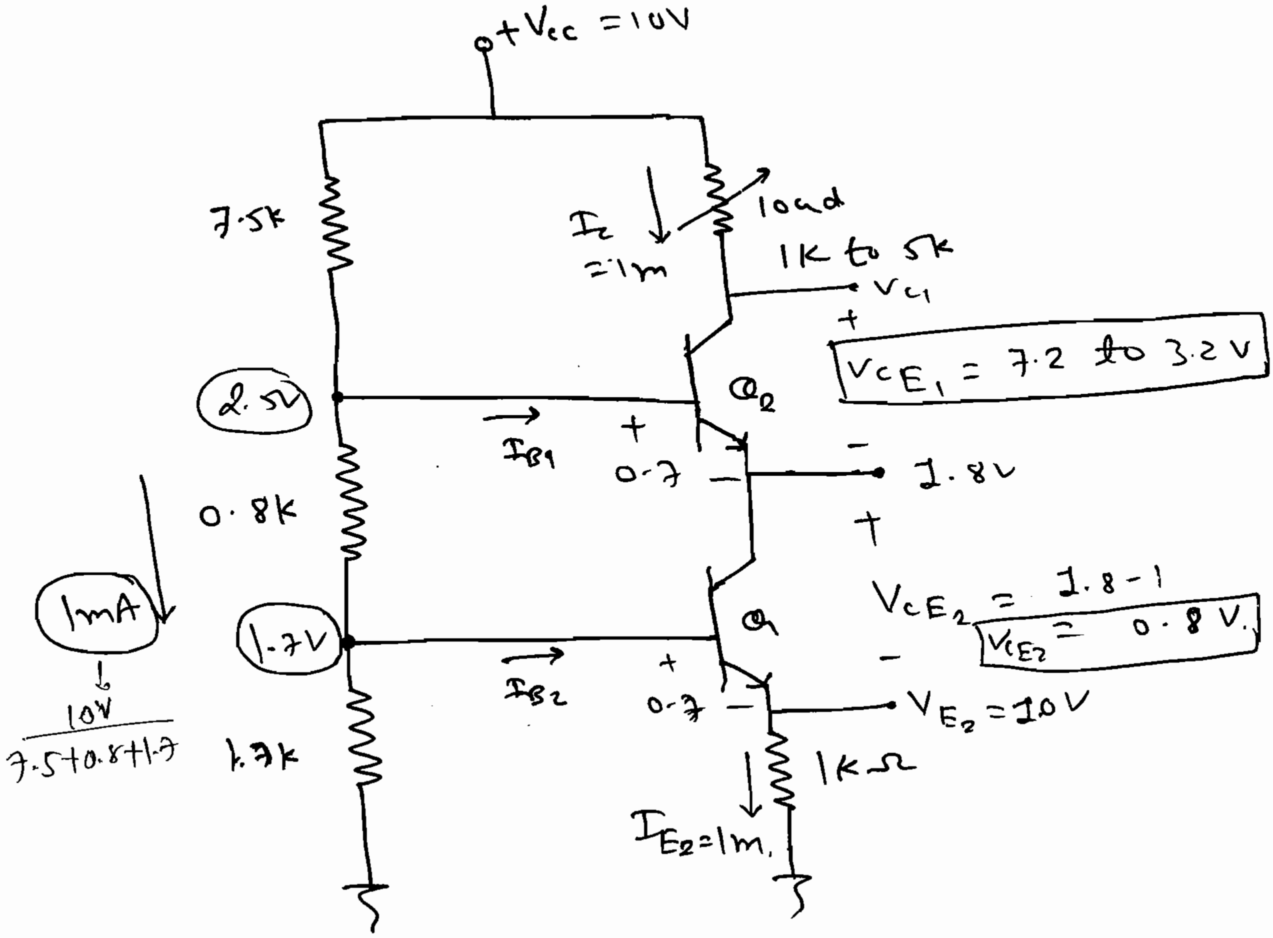
$\therefore \dfrac{V_o - V_B}{150} = \dfrac{I_E}{\beta+1}$.

$\therefore V_o - 2.7 = \dfrac{150 \times 1.7}{101}$

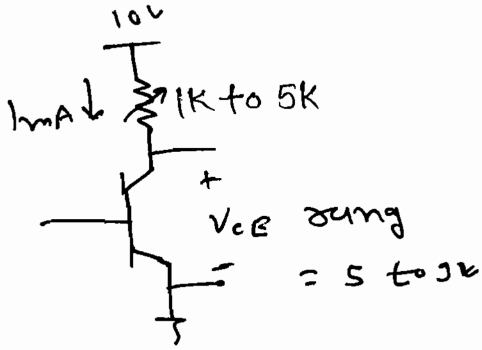
$\boxed{V_o = 5.224\text{ V}}$

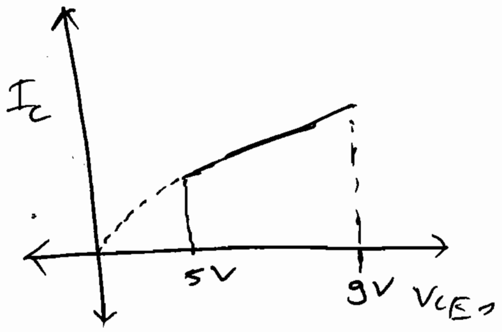
✩ Cascode Current Source for improved Stability on load Variations.

⇒



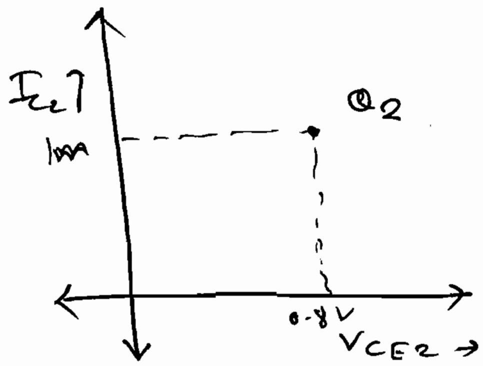
→





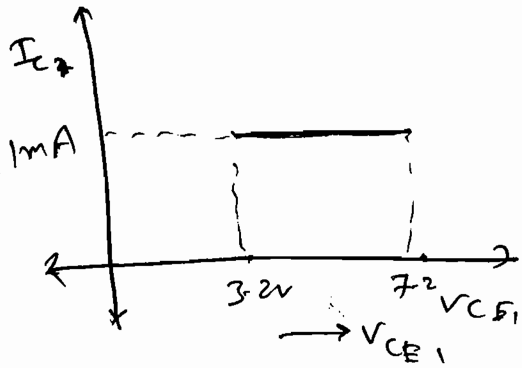
early effect.

→



[for Q_2]

→

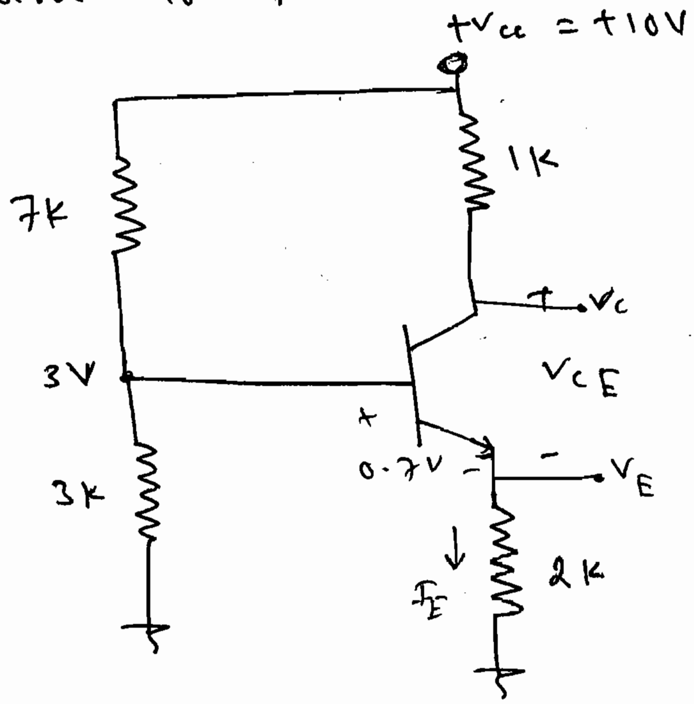


$$R_o = \frac{1}{\text{Slope}} = 1/0 = \infty$$

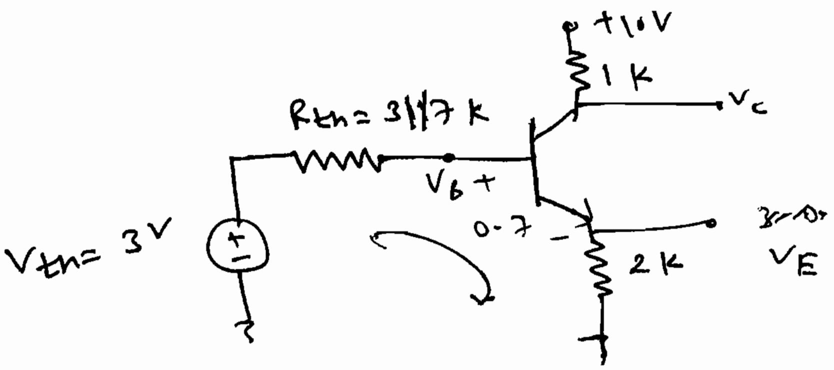
ideal current source

load	V_{CE_2}	V_{CE_1}	I_C
1K	0.8	7.2 V	1mA
2k	0.8	6.2 V	1mA
3K	0.8	5.2 V	1mA
4K	0.8	4.2 V	1mA
5K	0.8	3.2 V	1mA

Ex-1 Calculate all node voltages and Branch current if $\beta = 100$.



Ans:



$$\rightarrow \quad V_{th} - \frac{I_E}{\beta+1} R_{th} - V_{BE} - I_E R_E = 0$$

$$\therefore \quad I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta+1}}$$

$$R_{th} = \frac{3 \times 7}{10}$$

$$R_{th} = 2.1 \text{ k}\Omega$$

$$\therefore \quad I_E = \frac{3 - 0.7}{2 + \frac{2.1}{101}}$$

$$I_E = \frac{2.3}{2.02}$$

$$\therefore \boxed{I_E = 1.14\,mA.}$$

$$\therefore I_C = \frac{\beta}{\beta+1} \times I_E.$$

$$\therefore I_C = \frac{100}{101} \times 1.14\,mA$$

$$\therefore \boxed{I_C = 1.127\,mA}$$

$$\therefore V_C = V_{CC} - I_C R_C$$

$$\therefore V_C = 10 - (1.127 \times 1\,k).$$

$$\therefore \boxed{V_C = 8.87\,V} *$$

$$I_B = \frac{I_E}{\beta+1}.$$

$$\boxed{I_B = 11.29\,\mu A}$$

$$V_E = I_E R_E.$$

$$\therefore \boxed{V_E = 2.28\,V} *$$

$$\therefore \frac{V_{th} - V_B}{2.1\,k} = I_B.$$

$$\therefore 3 - V_B = 11.29 \times 10^{-6} \times 2.1\,k$$

$$\therefore 3 - V_B = 0.024.$$

$$\therefore \boxed{V_B = 2.976\,V} *$$

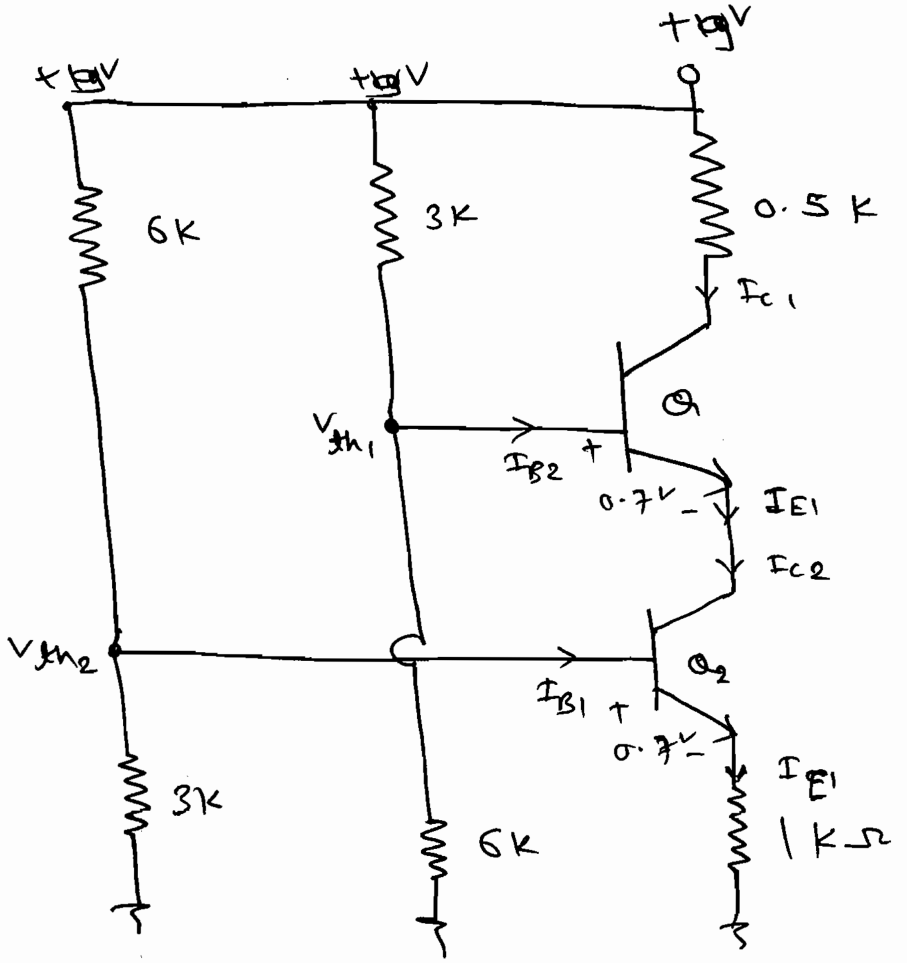
$$V_{CE} = V_C - V_E$$

$$\therefore V_{CE} = 8.87 - 2.28$$

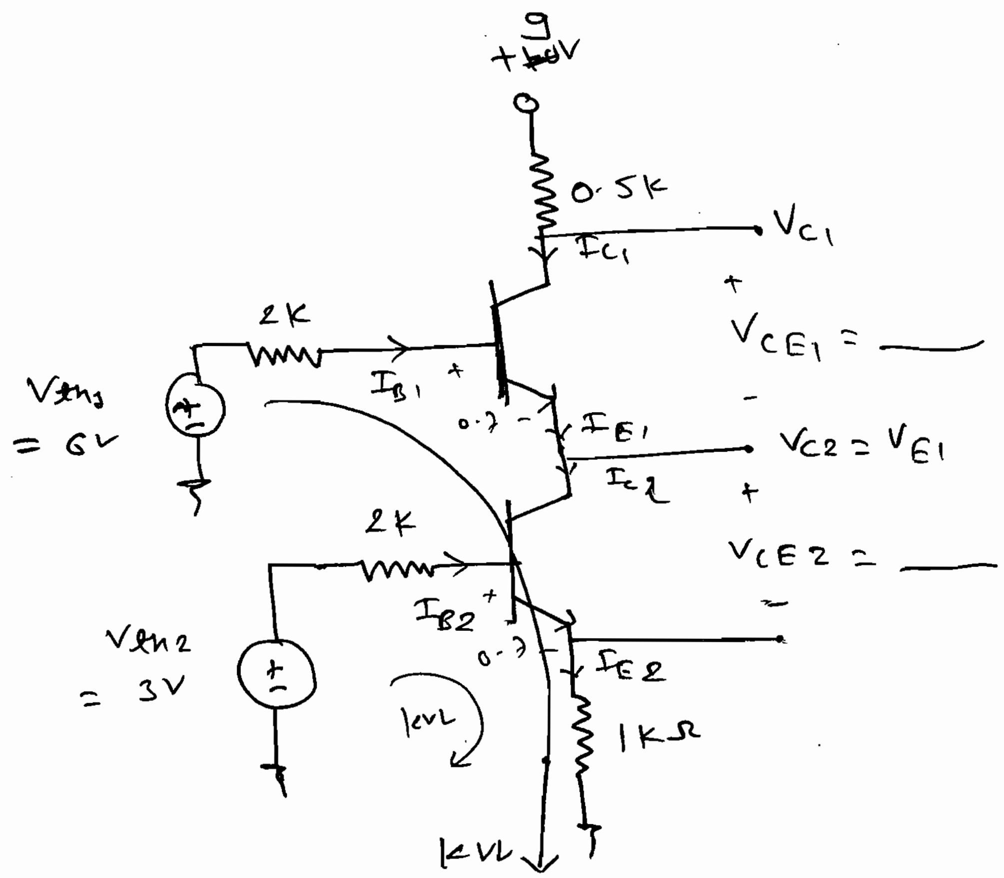
$$\therefore \boxed{V_{CE} = 6.59\,V}$$

Ex-2 Calculate the all the Node Voltages and Branch currents.

⇨



Ans:



$$\therefore \quad I_{E2} = \frac{V_{th2} - V_{BE2}}{R_E + \frac{R_{th1}}{\beta+1}}$$

$$R_{th1} = \frac{3 \times 6}{9}$$

$$R_{th1} = 2\,K.$$

$$\therefore \quad I_{E2} = \frac{3 - 0.7}{1 + \frac{2}{101}}$$

$$V_{th1} = \frac{3}{8} \times 8$$

$$V_{th1} = 3\,V.$$

$$\therefore \quad \boxed{I_{E2} = 2.255\ mA}$$

$$\therefore \quad I_{C2} = \frac{\beta}{\beta+1} \times I_{E2}.$$

$$\therefore \quad I_{C2} = \frac{100}{101} \times 2.255$$

$$\therefore \quad \boxed{I_{C2} = 2.23\ mA}$$

$$\therefore \quad I_{B2} = \frac{I_{E2}}{\beta+1}.$$

$$\therefore \quad \boxed{I_{B2} = 22.33\ \mu A.}$$

$$\therefore \quad I_{E1} = I_{C2}.$$

$$\therefore \quad \boxed{I_{E1} = 2.23\ mA.}$$

$$\therefore \quad I_{C1} = \frac{\beta}{\beta+1} \times I_{E1}$$

$$\therefore \quad I_{C1} = \frac{100}{101} \times 2.23$$

$$\therefore \quad \boxed{I_{C1} = 2.21\ mA.}$$

$$\therefore \quad I_{B1} = \frac{I_{E1}}{\beta+1} \quad \therefore \quad \boxed{I_{B1} = 22.08\ \mu A}$$

$\therefore \; V_{E_2} = I_{E_2} \times R_{E_2}$

$\therefore \; V_{E_2} = 2.255 \times 1$

$\therefore \; \boxed{V_{E_2} = 2.255\,V}$ *

$\therefore \; V_{C1} = 9 - I_{C_1} R_{C_1}$

$\therefore \; V_{C1} = 9 - (2.21 \times 0.5).$

$\therefore \; \boxed{V_{C1} = 7.895\,V}$ *

$\therefore \; V_{th_1} - I_{B1} R_{th_1} - 0.7 - V_{CE2} - I_{E_2} R_{E_2} = 0.$

$\therefore \; V_{CE2} = 6 - (0.02208 \times 2) - 0.7 - (2.255 \times 1)$

$\therefore \; \boxed{V_{CE2} = 3\,V}$ ☆

$\therefore \; V_{CE2} = V_{C2} - V_{E2}$

$\therefore \; V_{C2} = 3 + 2.255$

$\therefore \; \boxed{V_{C2} = 5.255\,V}$ *

$\therefore \; V_{E1} = V_{C2}$

$\therefore \; \boxed{V_{E1} = 5.255\,V}$ *

$\therefore \; V_{CE1} = V_{C1} - V_{E1}$

$\therefore \; V_{CE1} = 7.895 - 5.255$

$\therefore \; \boxed{V_{CE1} = 2.64\,V.}$ ☆

$\frac{V_{th_1} - V_{B1}}{R_{th_1}} = I_{B1}$

$\therefore \; V_{B1} = V_{th_1} - I_{B1} R_{th_1}$

$\therefore \; V_{B1} = 6 - (0.02208 \times 2).$

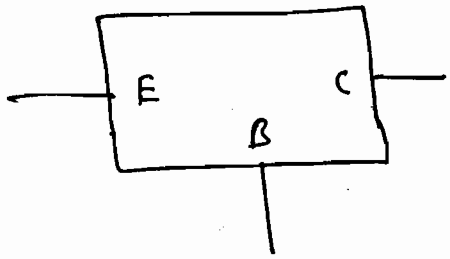
$\boxed{V_{B1} = 5.9558\,V}$ *

$V_{B2} = V_{th_2} - I_{B2} R_{th_2}$

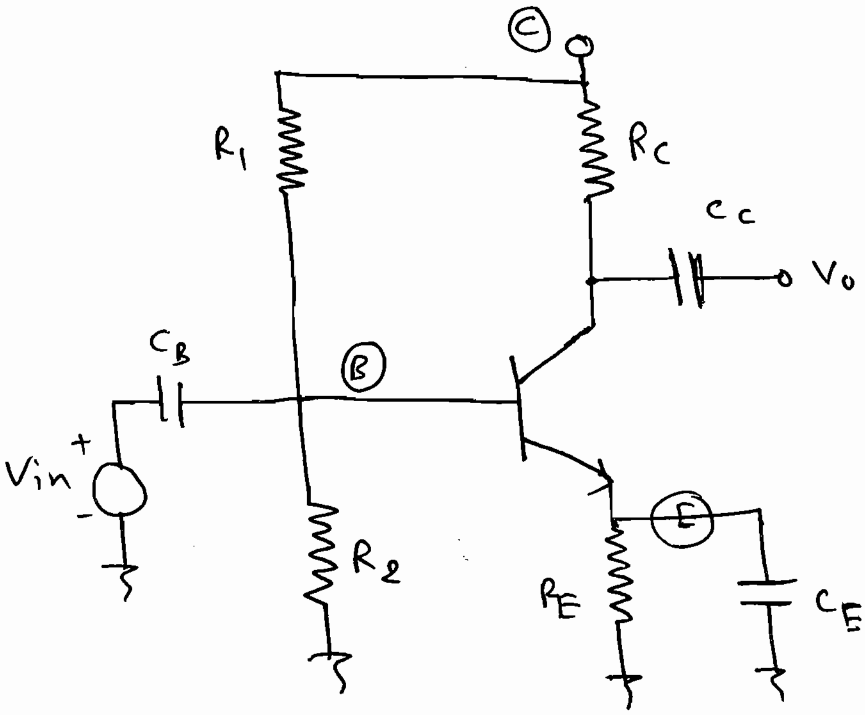
$\therefore \; \boxed{V_{B2} = 2.955\,V}$ *

☆ Configuration of BJT:

1) Common Emitter
2) Common Base
3) Common Collector



① Common Emitter:



$Z_{in} = 1\ k\Omega$

$Z_o = 50\ k\Omega$

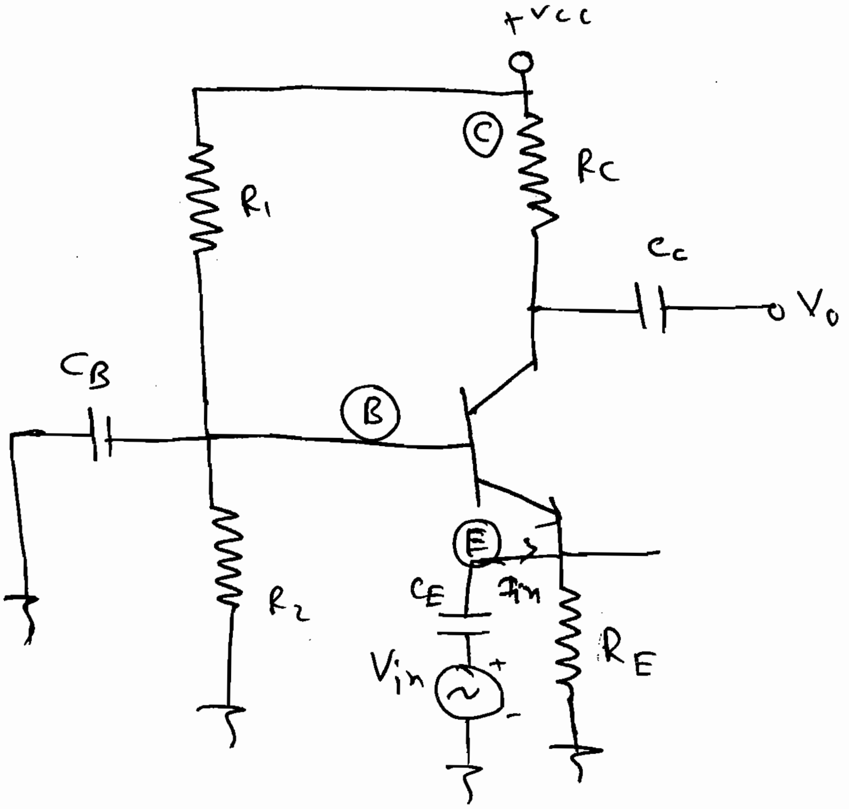
$A_V = -200$

$A_I = -100$

$A_P = A_V A_I$

Very high power gain.

② Common Base:



$$Z_{in} = \frac{V_{in}}{R_{in}} = 30\,\Omega. \Rightarrow CC$$

$\therefore$ $Z_o = 1\,M\Omega \Rightarrow CS$

$\therefore$ CB $\Rightarrow$ CCCS.

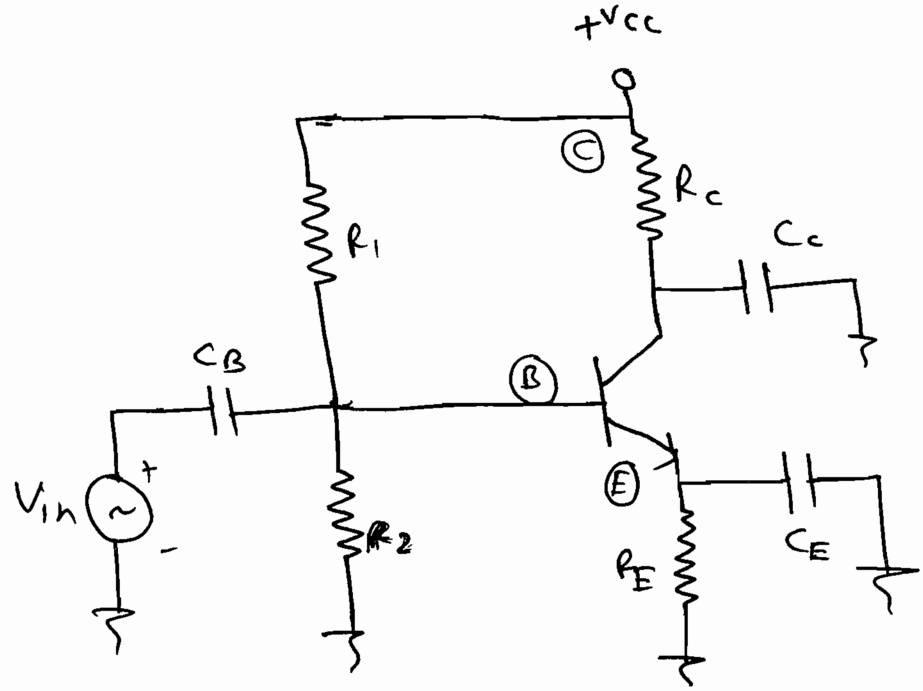
$\rightarrow$ $A_I = 1 \Rightarrow$ <u>Current Buffer</u>

$\therefore$ $A_V = 600$

$\therefore$ $A_P = A_V \cdot A_I$

$A_P = 600.$

(3) Common Collector:



$Z_{in} = 9\,M\Omega$ (VC).

$Z_o = 8\,\Omega$ (VS).

$\boxed{CC \rightarrow VCVS}$

$A_V = 1$ $\longrightarrow$ voltage Buffer

$A_I = 100.$

$\therefore A_P = A_V \cdot A_I$

$\therefore \boxed{A_P \cong A_I}$

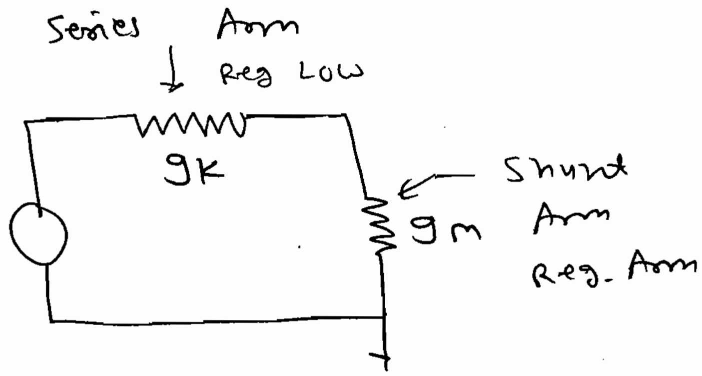
* Input impedence is found for Impedence matching.

* Output Resistance is found for Maximum power transfer.

If O/P Resistance = Load Resistance

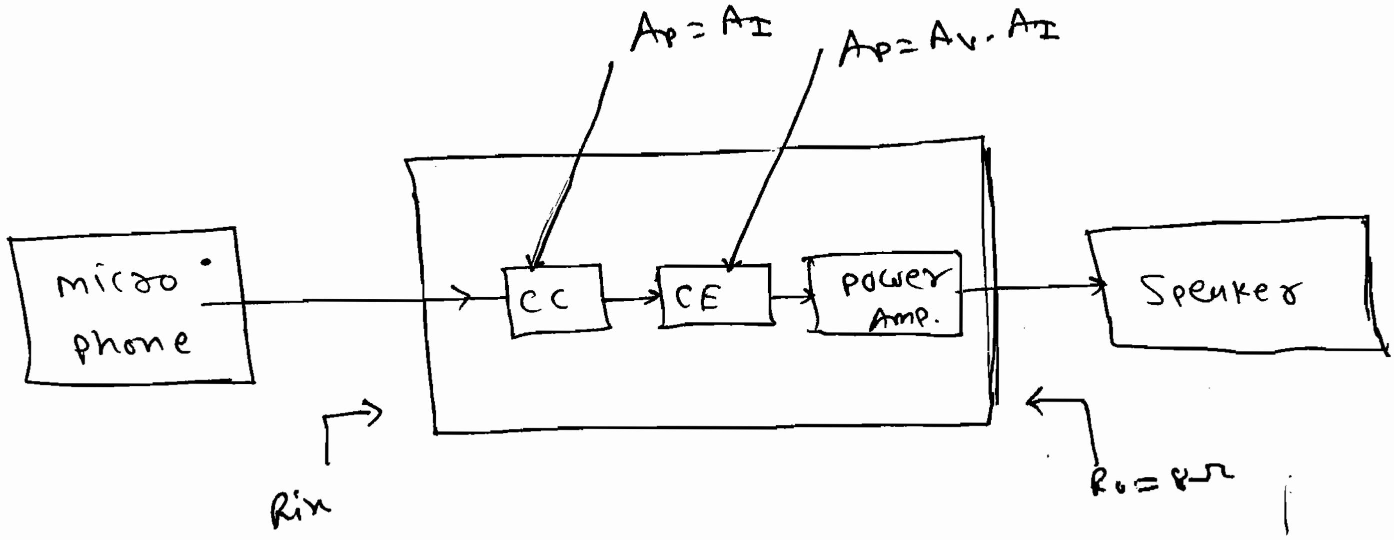
⇓

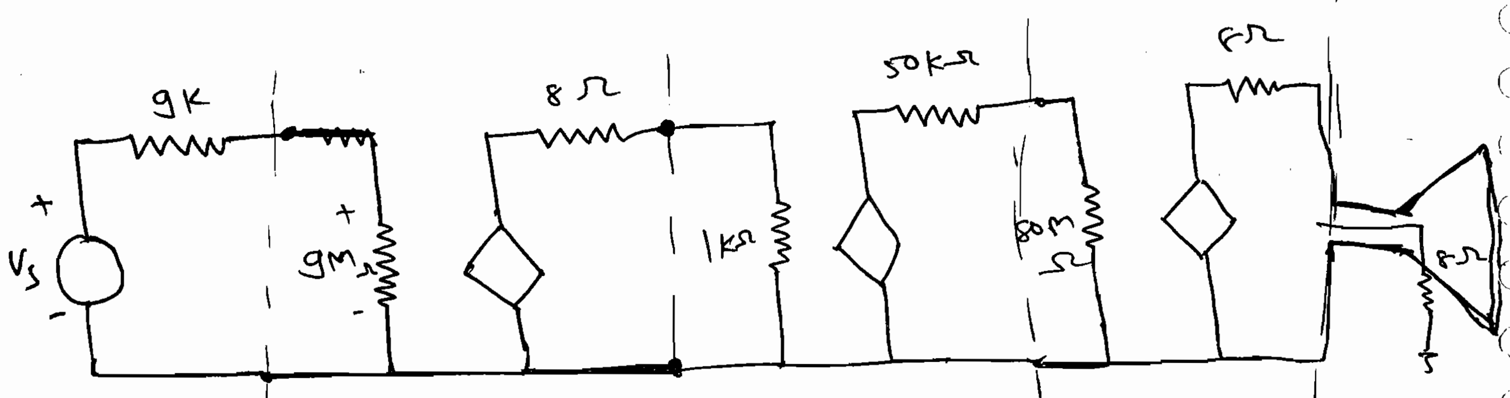
Maximum power can be transfered.



⇒ Good Ampⁿ.

*





Microphone (Source)

$\boxed{CC}$

- Rin = high

R_o = Low

$\boxed{VCVC}$

$A_P = A_I$

$\boxed{CE}$

Rin = Moderate

R_o = "

$A_P = A_V \cdot A_I$

$\boxed{\text{Power Amp}}$

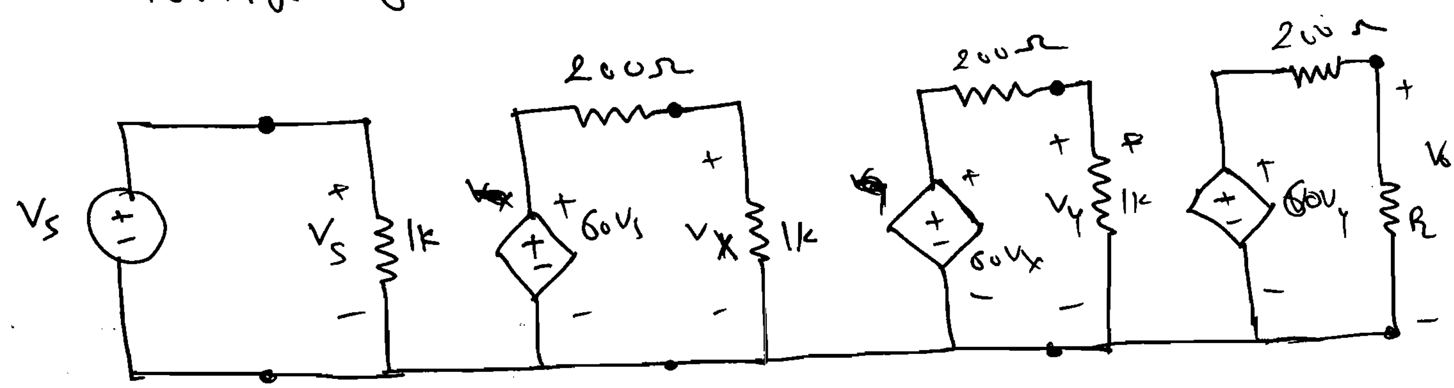
(Speaker) (Load)

← Amplifier →

Ex :(1) An Amp has an input Resistor of 1 kΩ, o/p Resistor = 200Ω. If and open loop voltage gain $A_o = 60$. If 3 similar stages cascaded with a load Resistor $R_L = 2.2K$. Find the over all voltage gain.

GATE

Imp



$$\therefore A_v = \frac{V_o}{V_s} = \frac{V_o}{V_y} \times \frac{V_y}{V_x} \times \frac{V_x}{V_s}.$$

$$\therefore V_x = \frac{60 V_s \times 1K}{200 + 1K}$$

$$\therefore \boxed{V_x = 50.} V_s$$

$$\therefore \boxed{\frac{V_x}{V_s} = 50.}$$

$$\therefore V_y = \frac{60 V_x \times 1000}{1200}$$

$$\therefore \boxed{\frac{V_y}{V_x} = 50}$$

$$\therefore V_o = \frac{60 V_y \times 2200}{2400}$$

$$\boxed{\frac{V_o}{V_y} = 55.}$$

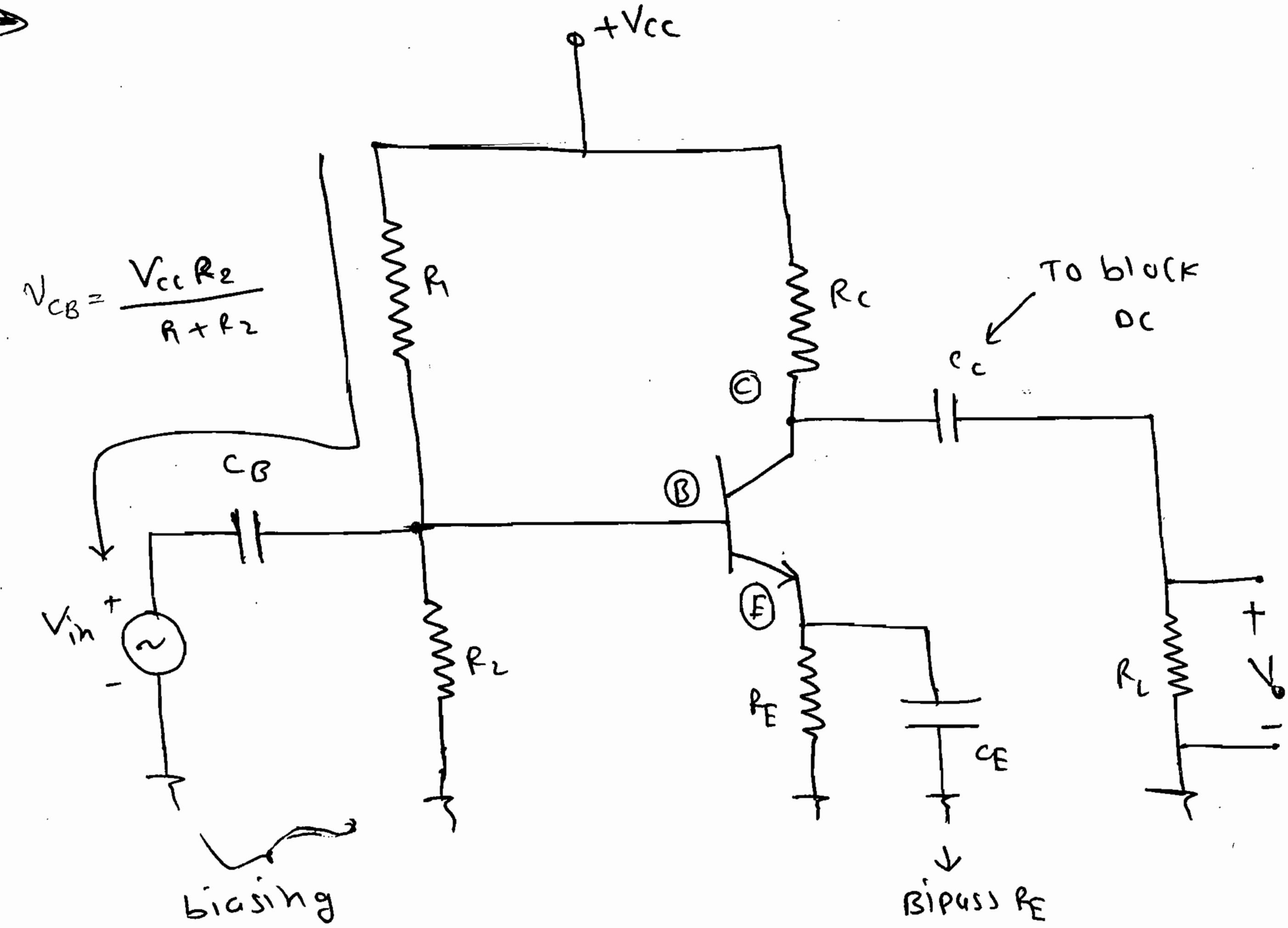
$$\therefore A_v = 55 \times 50 \times 50$$

$$\boxed{A_v = 1.375 \times 10^5.}$$

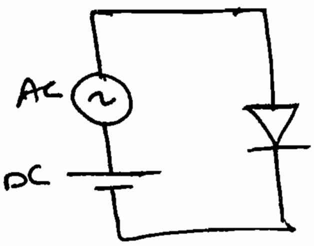
★ Small Signal Analysis of BJT :-

→

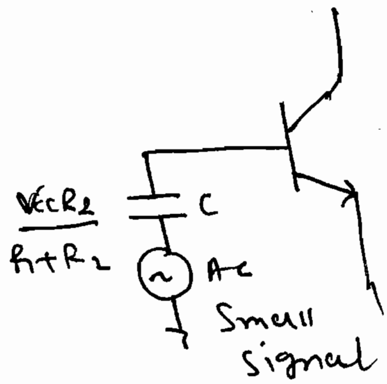
$$V_{CB} = \frac{V_{CC} R_2}{R_1 + R_2}$$



→



Non-linear ⇒ linear



Non linear ⇒ linear.

→ If load connected to Vcc it is called floating load and it is Rc coupled ckt.

→ If load is connected to ground then it is called grounded load and called Direct coupled ckt.

* Purpose of each capacitor:

→ ① C_B → for DC biasing.

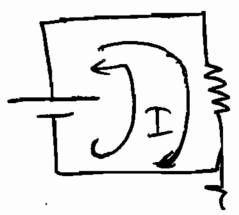
② C_E → To block DC and allow AC in V_o.

③ ~~C1~~ $\boxed{C_E}$ → Bypass C_E.

→ (i) C_E behaves as open circuit for DC signal and it allows R_E to play its Role in establishing β independent DC collector current. $(I_{C_{DC}})$.

(ii) C_E behaves as short circuit for AC signal eliminating the Gain Reducing emitter Resistor.

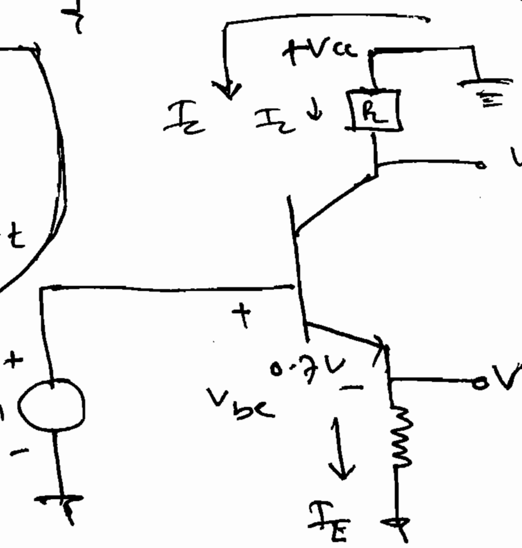
*



→ Going to ground $V = IR$

→ Coming from ground. $V = -IR$.

CE ~~Amp~~. BJT gives 180° phase shift as we get '-' in V_o.



$$V_{in} = V_{be} + I_E R_E$$

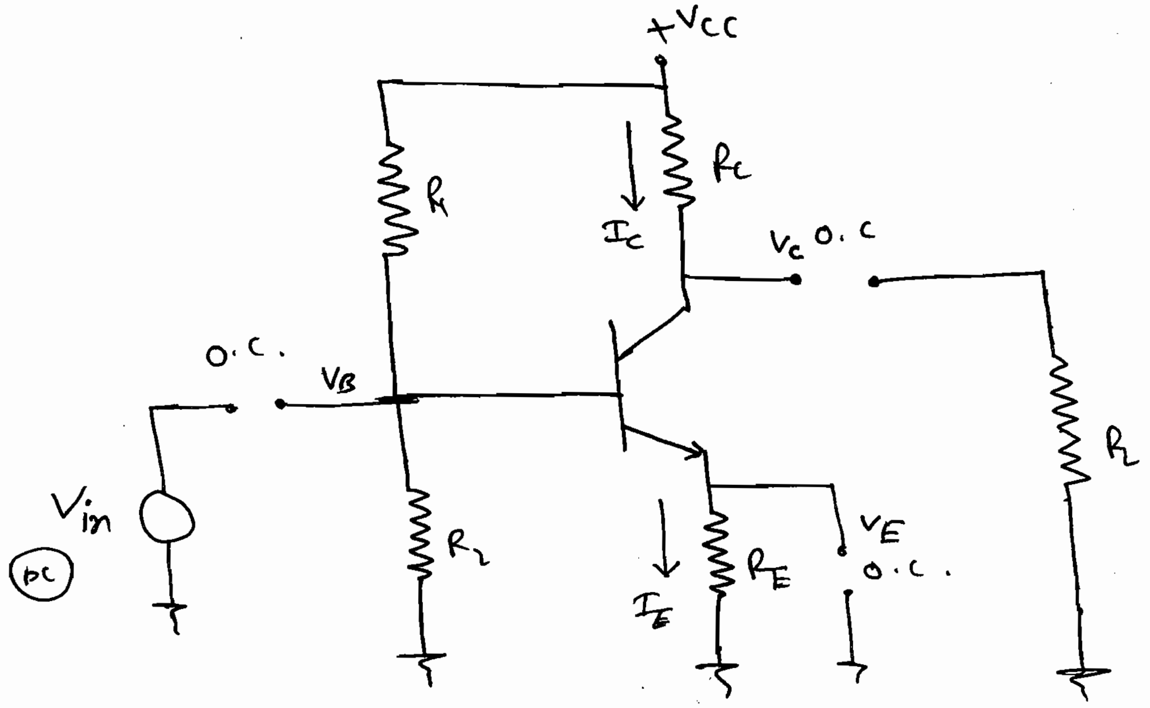
$$\therefore A_v = \frac{V_o}{V_{in}}$$

$$\therefore \boxed{A_v = \frac{-I_c R_c}{V_{be} + I_E R_E}}$$

① DC picture:

→ open circuit the all capacitor.

After that it is self bias.



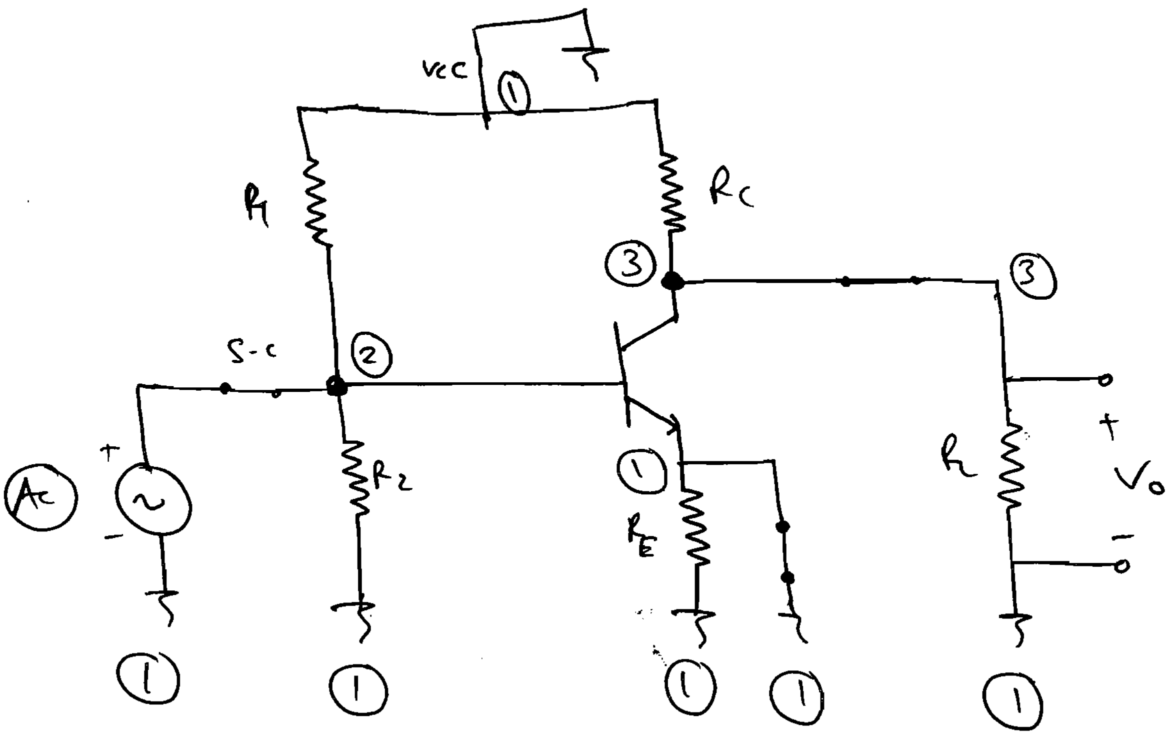
$$\therefore V_{c_{DC}} = V_{cc} - I_{c_{DC}} R_c$$

$$\therefore V_{c_{DC}} = V_{cc} - \left[\frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E + \frac{R_1 \| R_2}{\beta + 1}} \right] \cdot R_c$$

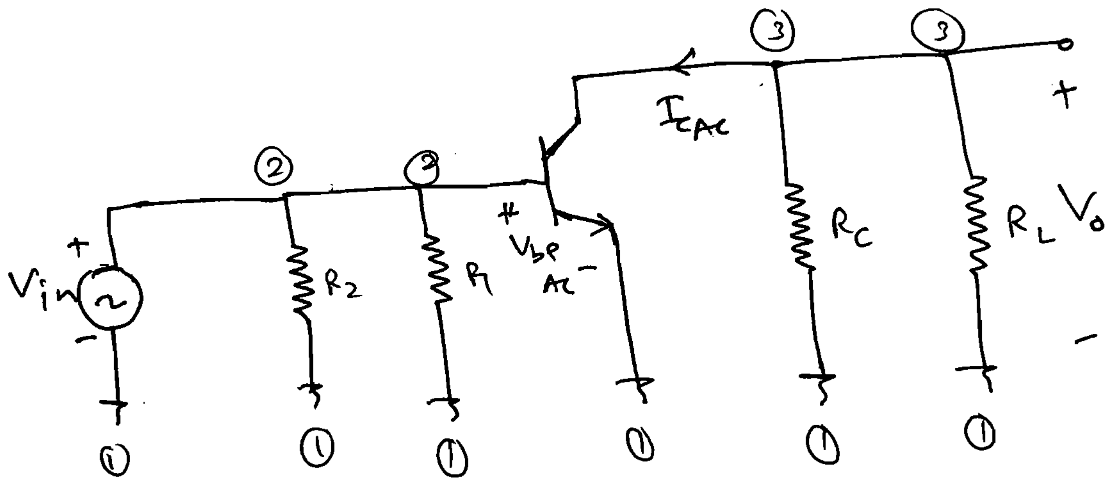
$$\rightarrow I_{c_{DC}} = I_E = \frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E + \frac{R_1 \| R_2}{\beta + 1}}.$$

(2) Ac Picture:

→ Short ckts all the capacitor and DC supply i.e. V_{cc}.



⇓



$$\therefore \quad V_o = -I_{C_{Ac}} \left(R_c \parallel R_L \right).$$

$$\therefore \quad V_{in} = V_{be\,(Ac)}.$$

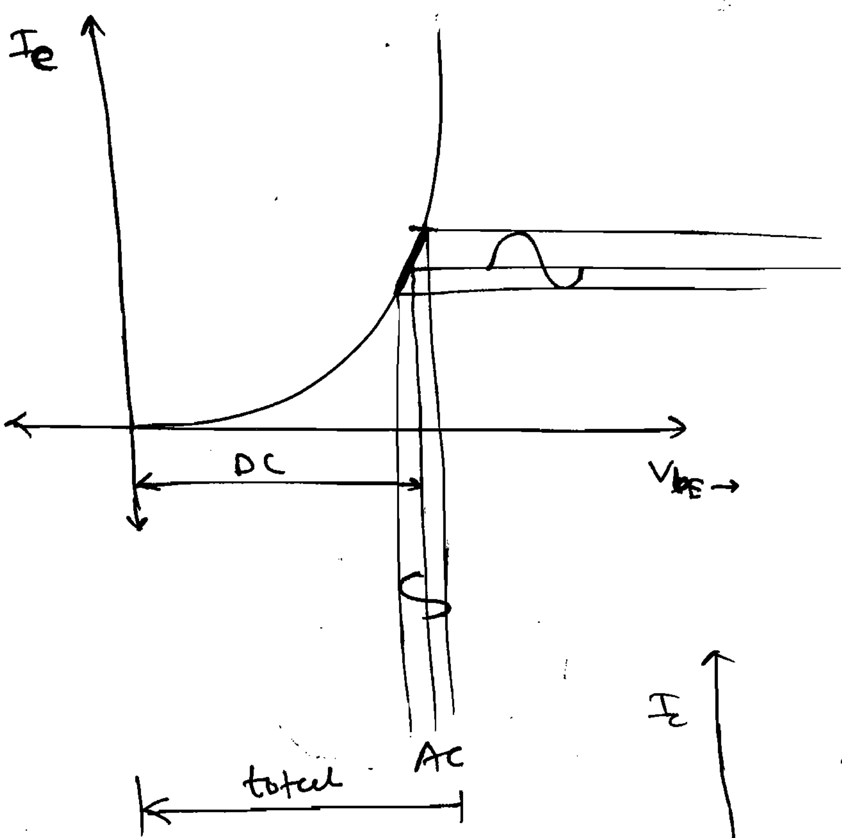
$$A_V = \frac{V_o}{V_{in}}$$

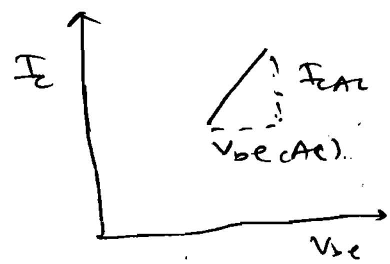
$$A_V = \frac{-I_{c(AC)}}{V_{be(AC)}} [R_C \| R_L].$$

$$\therefore \boxed{A_V = -g_m [R_C \| R_L].}$$

$\rightarrow$

$$I_c = I_S \cdot e^{V_{be}/V_t}$$





$$g_m = \frac{dI_c}{dV_{be}}$$

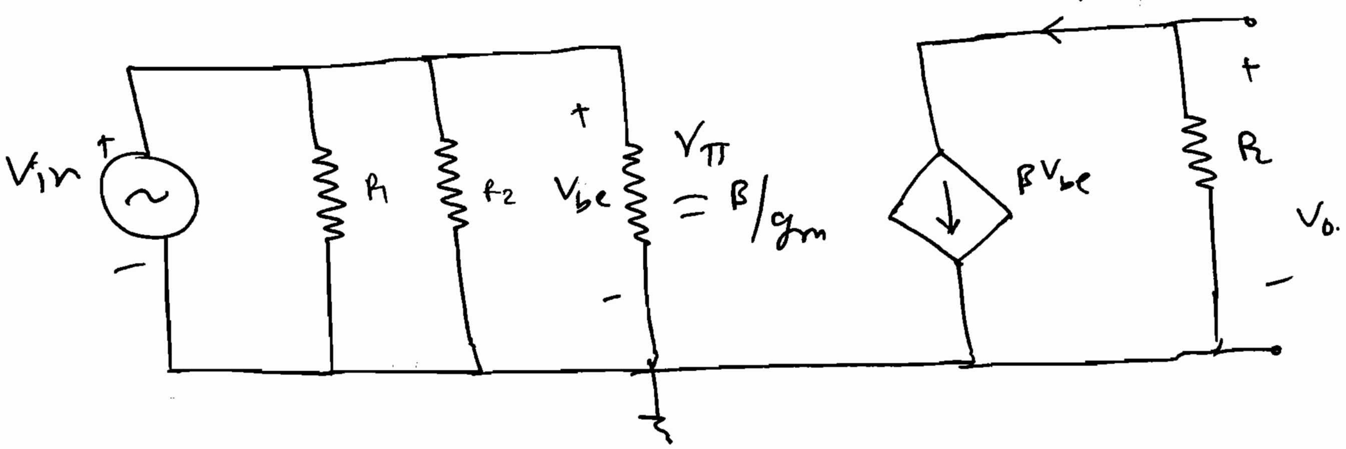
$$= I_S \cdot e^{V_{be_{DC}}/V_t} \cdot \frac{1}{V_t}$$

where

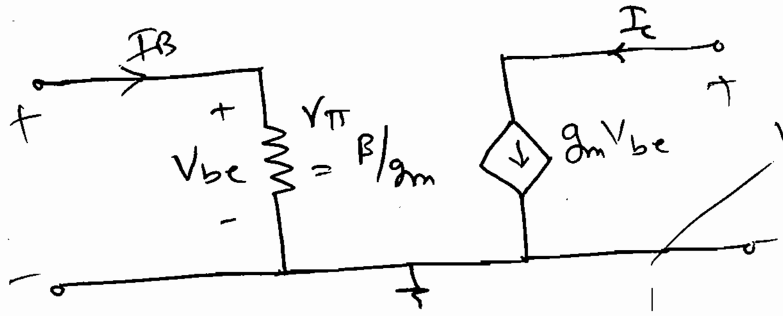
$$g_m = \frac{I_{cDC}}{V_t}.$$

$$\therefore g_m = \frac{I_{c.DC}}{V_t}$$

*



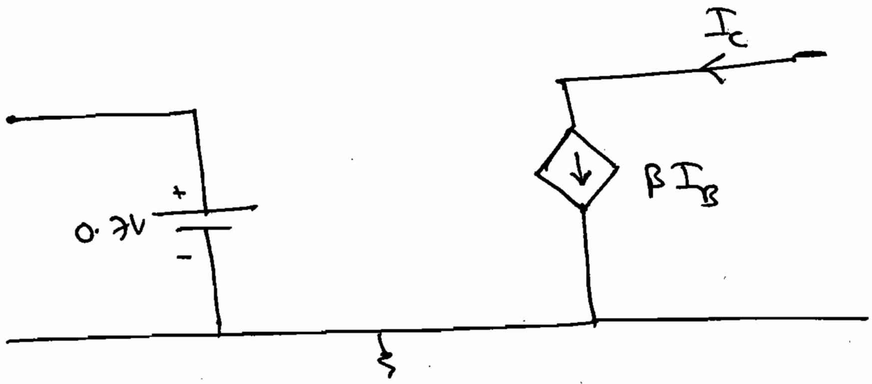
* AC model:



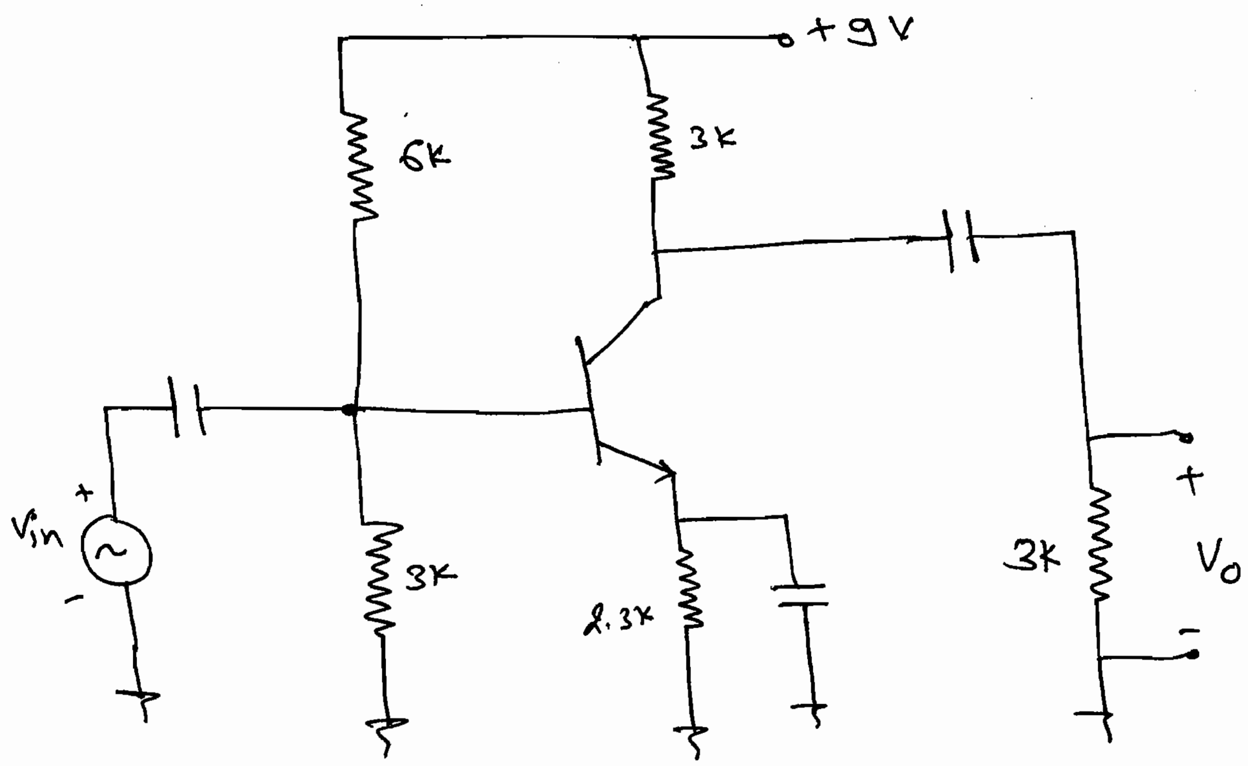
$$g_m = \frac{I_{C\,DC}}{V_t}.$$

r_π = Base to emitter resistance

* Dc model:



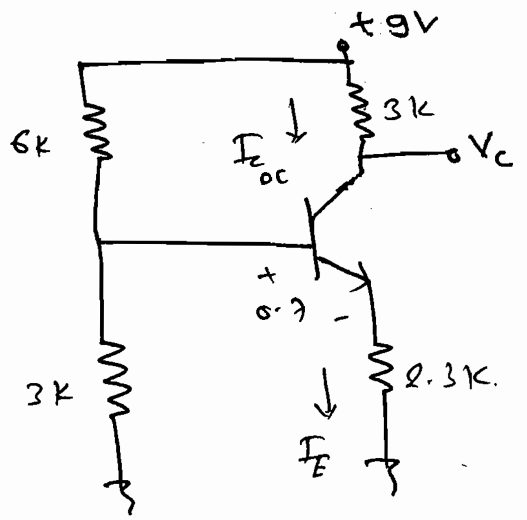
Ex-1 Find the voltage gain V_o/V_{in} if β is very large.



Ans:

① DC picture:

o.c. the capacitor



$\therefore$ $V_{th} = 3V.$, $R_{th} = 2k.$

$$\therefore I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta+1}}.$$

$$\therefore I_E = \frac{3 - 0.7}{2.3 + 0} \quad (\because \beta \gg \text{very large})$$

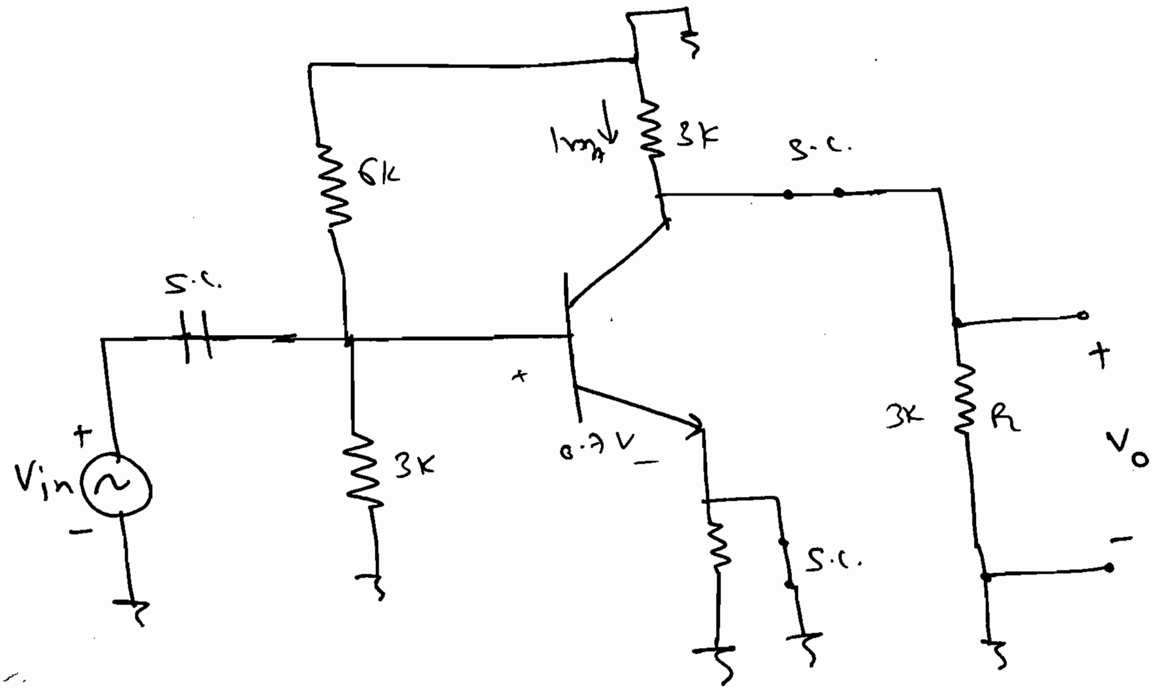
$\therefore \boxed{I_E = 1mA.}$

$$\therefore \quad I_{C_{DC}} = \frac{\beta}{\beta+1} \cdot I_E = I_E \quad (\because \beta \text{ is very large}).$$

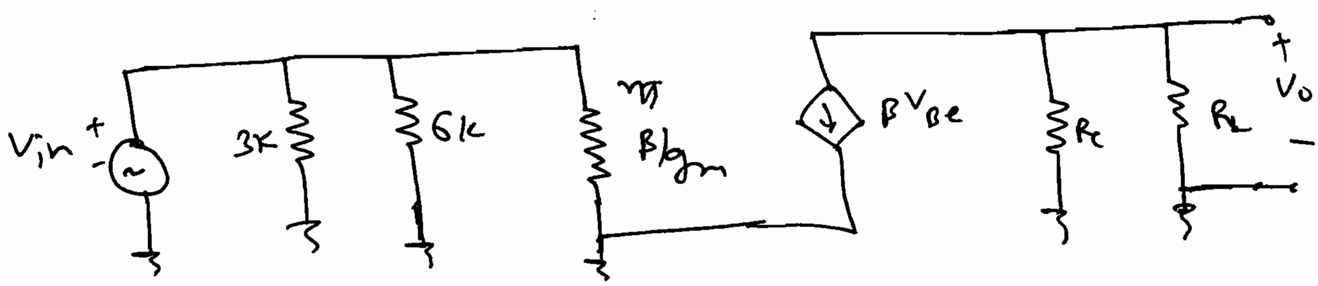
$\therefore \boxed{I_{C_{DC}} = 1mA}$

→ (2) Ac picture

s.c. capacitors and Dc sources.



|||



$$\therefore \frac{V_o}{V_{in}} = -g_m (R_c \| R_L).$$

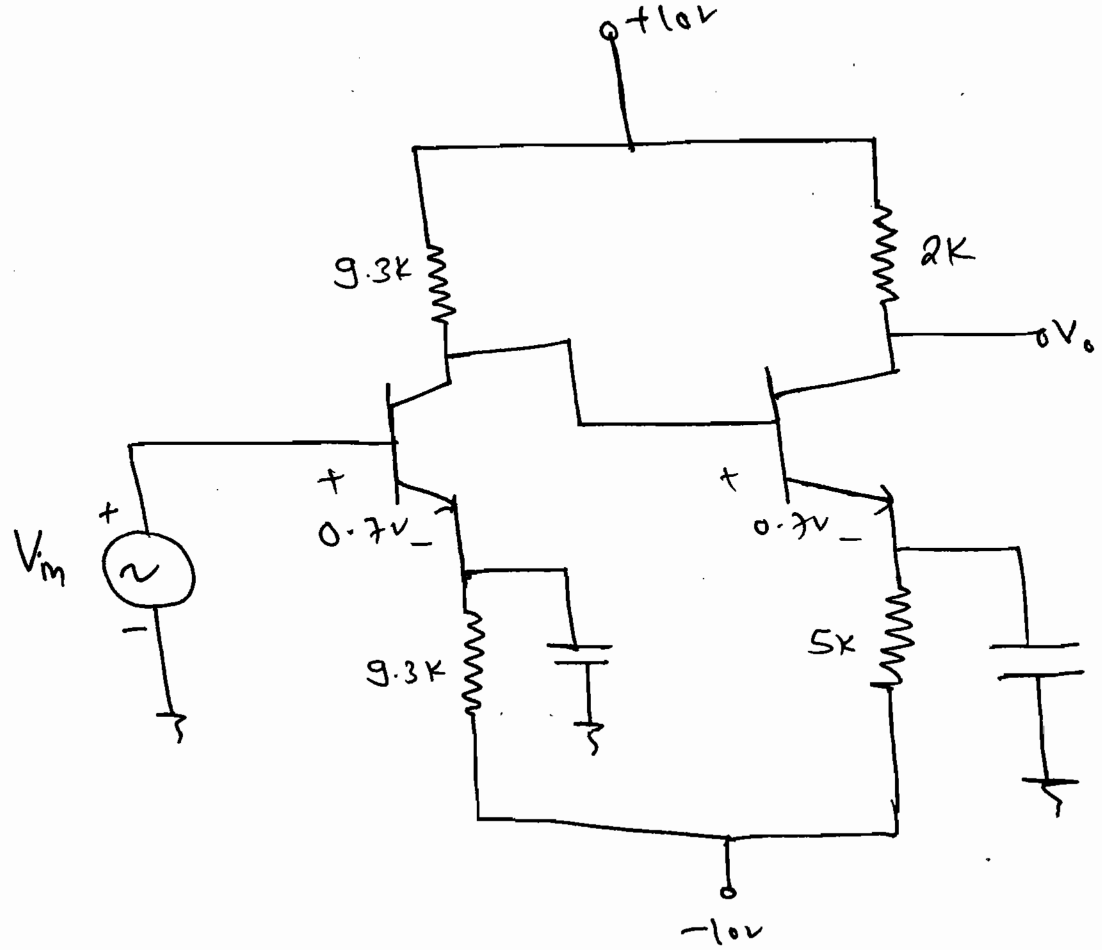
$$g_m = \frac{I_{DC}}{V_t}.$$

$$g_m = \frac{1m}{25m} = 0.04$$

$$\therefore \frac{V_o}{V_{in}} = -0.4 [1.5].k$$

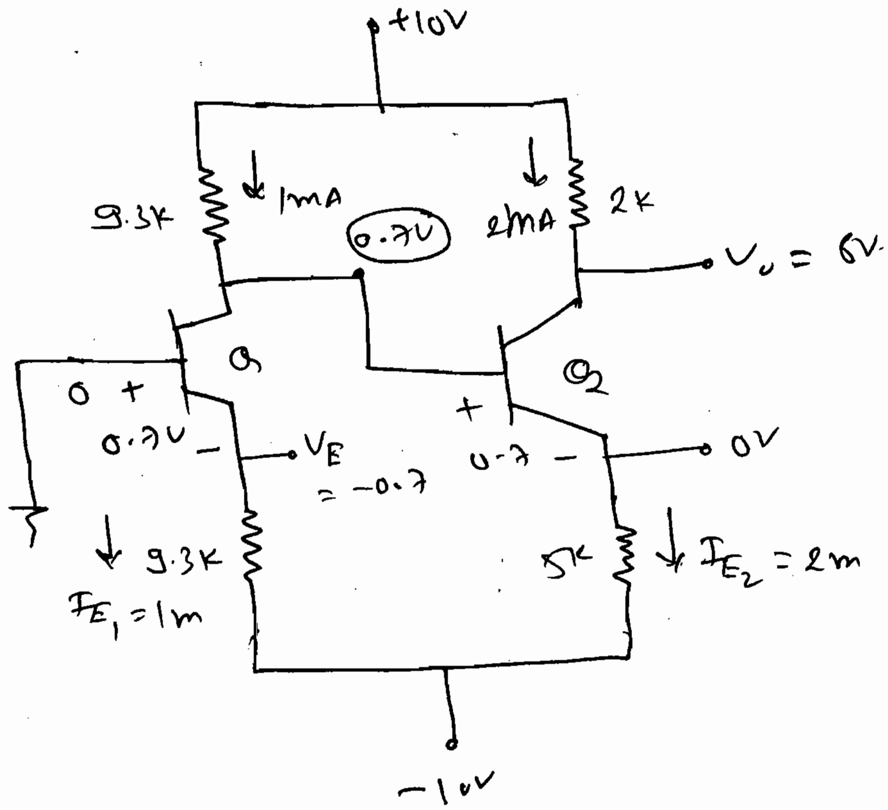
$$\neq \quad \frac{V_o}{V_{in}} = \frac{1}{-25} \times 1500 = 60 \qquad \therefore \boxed{\frac{V_o}{V_{in}} = -60}$$

Ex-2 Find V_o:



Ans:

① DC picture.



$\therefore \; V_{E_1} = 0 - 0.7$

$V_{E_1} = -0.7V$

$$\rightarrow \quad I_{E_1} = \frac{-0.7-(-10)}{9.3k}$$

$$= \frac{9.3}{9.3k}$$

$\therefore I_{E_1} = 1m$

$\therefore \boxed{I_{C_1\,DC} = 1m.}$

$\therefore V_{C_1} = 10 - (9.3 \times 1).$

$\boxed{V_{C1} = 0.7V}$

$\therefore V_{E2} = 0.7 - 0.7 = 0V.$

$\therefore I_{E2} = \frac{V_{E2} - (-10)}{5k}$

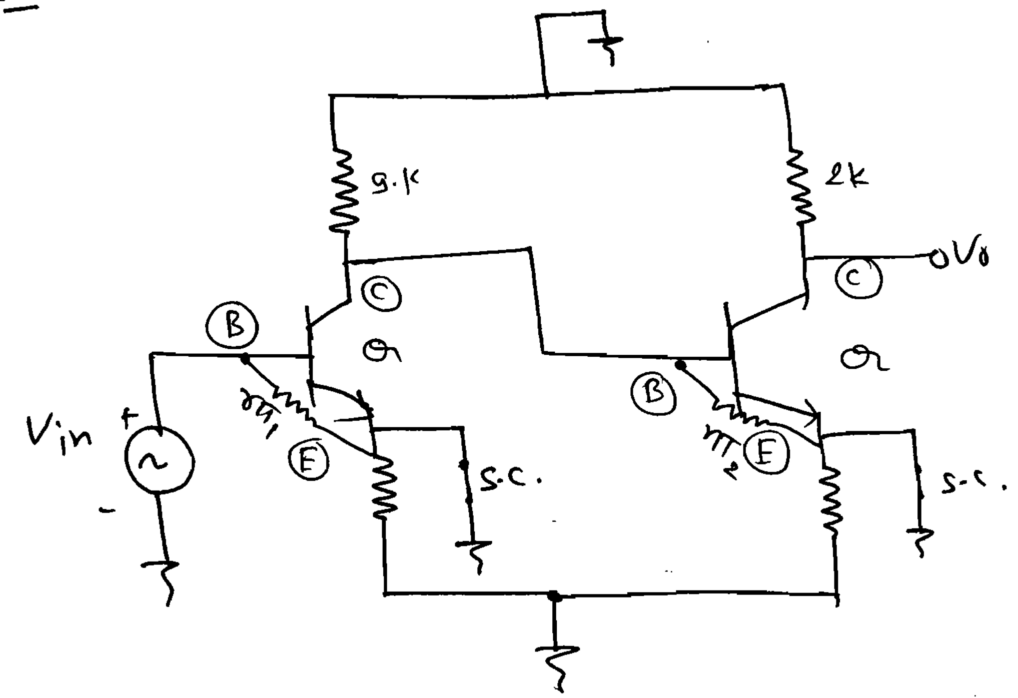
$I_{E2} = 2\,mA$

$\therefore V_o = 10 - (2(2))$

$\boxed{V_o = 6V}$

$\therefore \boxed{I_{C2\,DC} = 2mA.}$

② Ac picture:



Q1

$$g_{m1} = \frac{I_{C_{DC1}}}{V_t}$$

$$g_{m1} = \frac{1m}{25m}$$

$$\boxed{g_{m1} = \frac{1}{25}}$$

$$r_{\pi_1} = \beta / g_{m1}$$

$$r_{\pi 1} = \frac{100}{1/25}$$

$$\boxed{r_{\pi 1} = 2.5k\Omega}$$

Q2

$$g_{m2} = \frac{I_{C_{DC2}}}{V_t}$$

$$= \frac{2m}{25m}$$

$$\therefore \boxed{g_{m2} = \frac{2}{25}}.$$

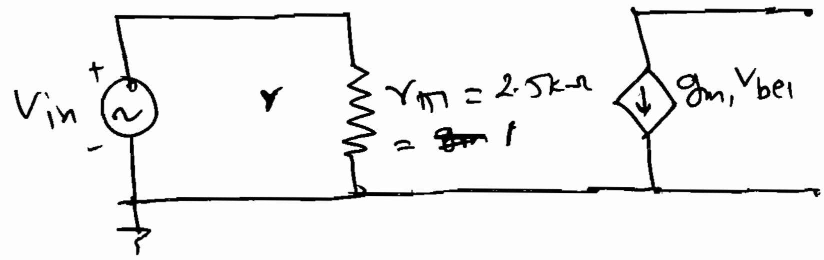
$$r_{\pi 2} = \beta / g_{m2}$$

$$\therefore r_{\pi 2} = 100/2/25$$

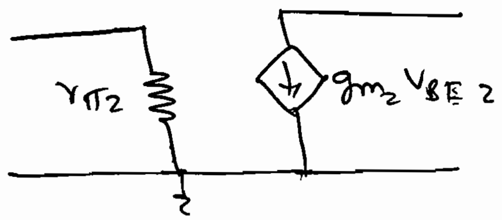
$$\therefore \boxed{r_{\pi 2} = 1.25k\Omega}$$

Now,

Q1



Q2



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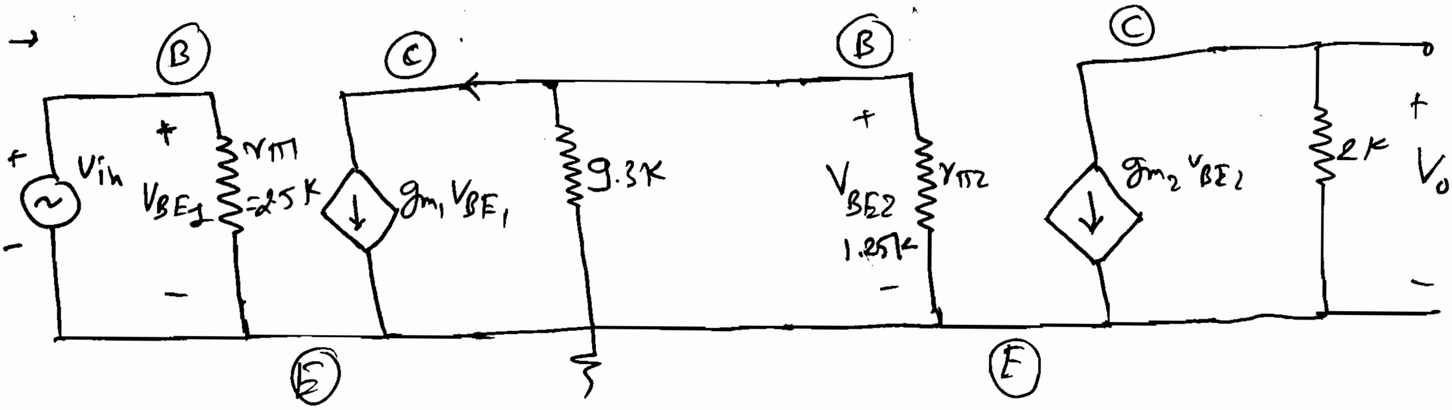


$$\therefore \frac{V_o}{V_{in}} = \frac{V_o}{V_{BE2}} \times \frac{V_{BE2}}{V_{BE1}}.$$

$$\therefore V_{BE_2} = -g_{m1} \cdot V_{BE1} \cdot (1.25k \parallel 9.3k).$$

$$\therefore \frac{V_{BE_2}}{V_{BE_1}} = -g_{m1}(1.25k \parallel 9.3k).$$

$$\therefore V_o = -g_{m2} V_{BE2} \ (2k).$$

$$\therefore \frac{V_o}{V_{in}} = -g_{m2}(2k) \times -g_{m1}(1.25k \parallel 9.3k).$$

$$= \frac{2}{25} \times \frac{1}{25} \times (2000)($$

$$\therefore \frac{V_o}{V_{in}} = A_V = 7052.$$

Now, $V_o = 7052 \times V_{in}$

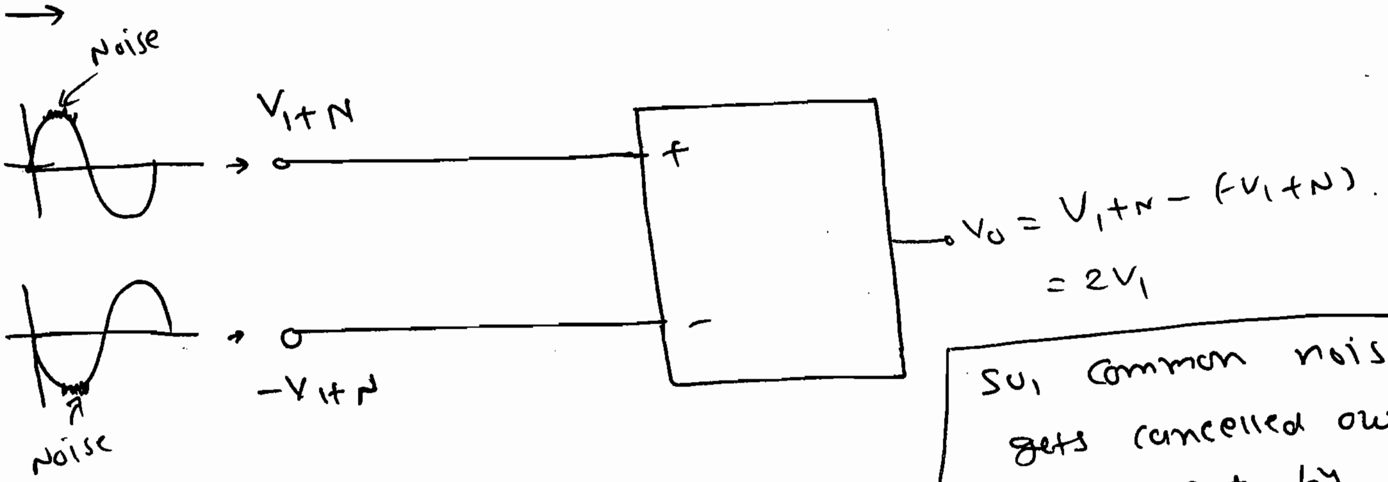
But $V_{in} = V_{BE1} = 0.7$

$$\therefore V_o = 7052 \times V_{BE1} = 7052 \times 0.7$$

$$\therefore \boxed{V_o = 4936.5V}$$

☆ Differential Amplifier:

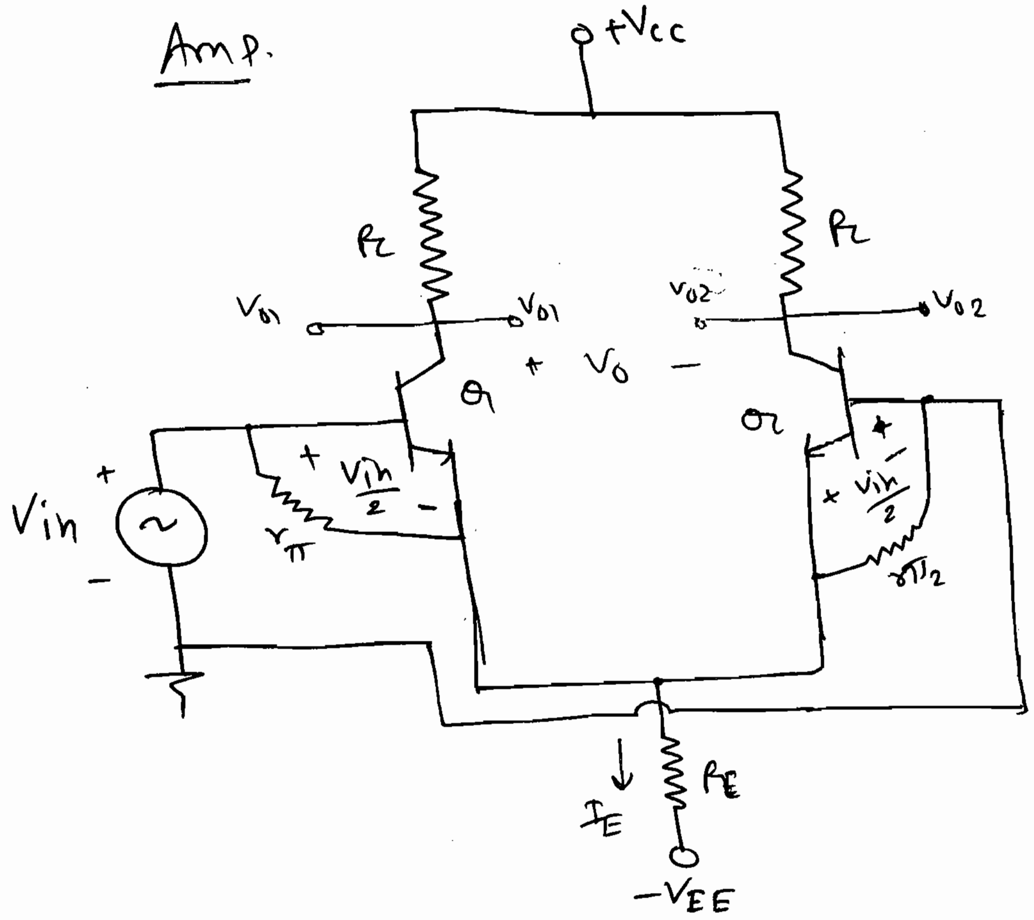
→



$V_0 = V_1+N - (-V_1+N)$
$= 2V_1$

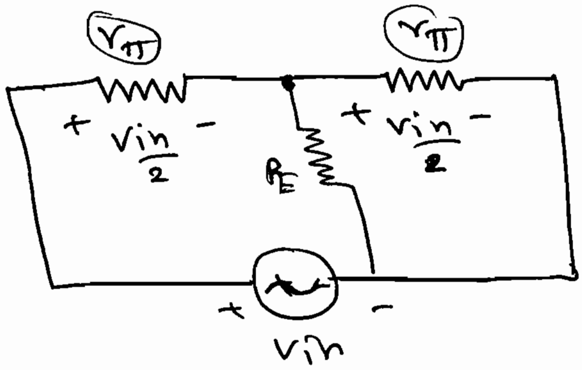
So, common noise gets cancelled out at output by taking differential measurement.

Direct Coupled Amp.



→ For DC analysis we will get $I_{C1_{DC}}$ & $I_{C2_{DC}}$.

Now, For AC.



→ Here, $R_E \gg r_\pi$ ($\because$ R_E is in $M\Omega$ and r_π is in $k\Omega$).

So. $R_E \| r_\pi \approx r_\pi$

So, R_E is shunted by r_π (dynamic resistance) as $R_E \gg r_\pi$.

Now, $V_{o1} = -I_{c_{DC1}} \cdot R_C$. $\qquad \frac{I_c}{V_{BE}} = -g_m.$

$\therefore V_{o1} = -g_m R_C . (V_{BE1})$

$\therefore V_{o1} = -g_m R_C \left(\frac{v_{in}}{2}\right)$ $\qquad$ ($\because V_{BE1} = \frac{V_{in}}{2}$ see fig.).

similiary

$\therefore V_{o2} = -g_m R_C \left(-\frac{V_{in}}{2}\right)$ $\qquad$ ($\because V_{BE_2} = -\frac{V_{in}}{2}$).

$\therefore V_o = V_{o1} - V_{o2}$

$= -g_m R_C \left(\frac{V_{in}}{2} - \left(-\frac{V_{in}}{2}\right)\right)$

$\therefore \boxed{V_o = -g_m R_C \, V_{in}}$

So, $\boxed{A_v = \frac{V_o}{V_{in}} = -g_m R_C.} = A_d$ ← gain of diff ampr

* → CE amplifier suffers from all common problem. (Noise, drift etc.)

→ Diff. Amplifier eliminates such kinds of all these problem.

→ CE amplifier practically never used.

NOTE:

→ Differential Amplifier is a Basic Building Block of Analog IC designe.

→ Need for voltage divider and Coupling Capacitor to bias the BJT is eliminated in differential amplifier with -ve supply.

→ The need for the Bypass Capacitor is eliminated in a differential amplifier with two symmetrical structure (OR) with a two symmetrical circuit.

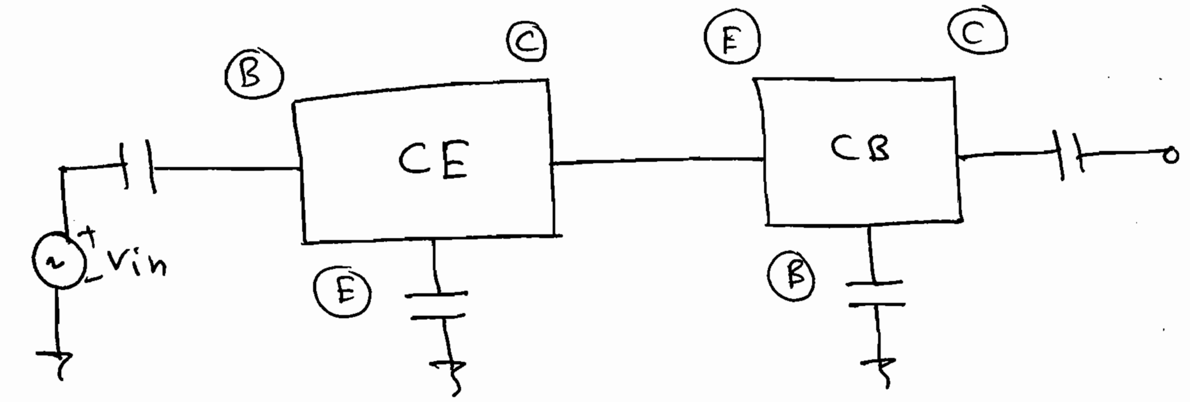
→ O/P Capacitor is eliminated By differential measurement.

→ The input capacitor is eliminated by Negative supply.

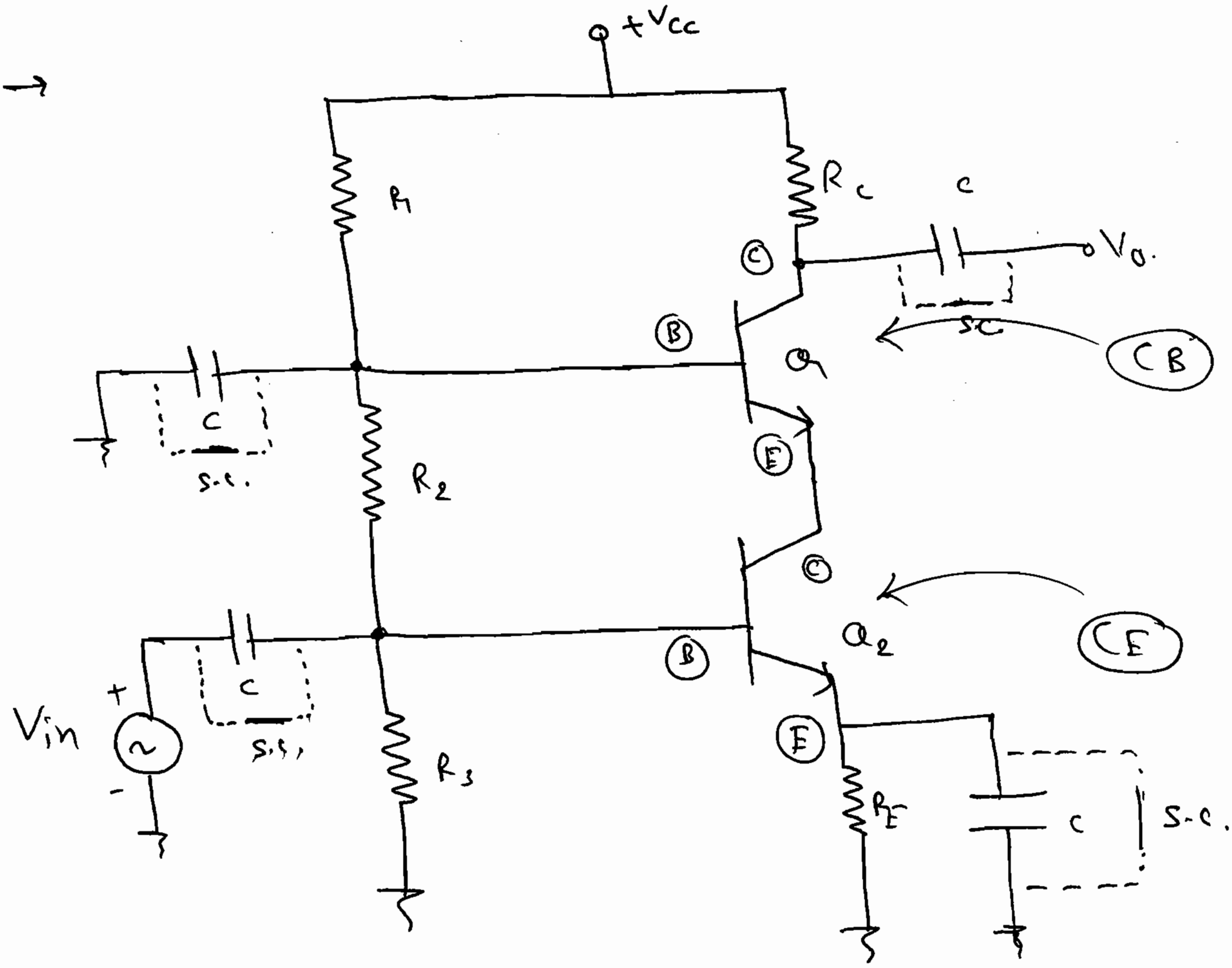
→ Capacitor has to be eliminated because it takes more space in circuites and the soln of this problem is differential amplifier.

Cascode Amplifier [Wide Band structure]

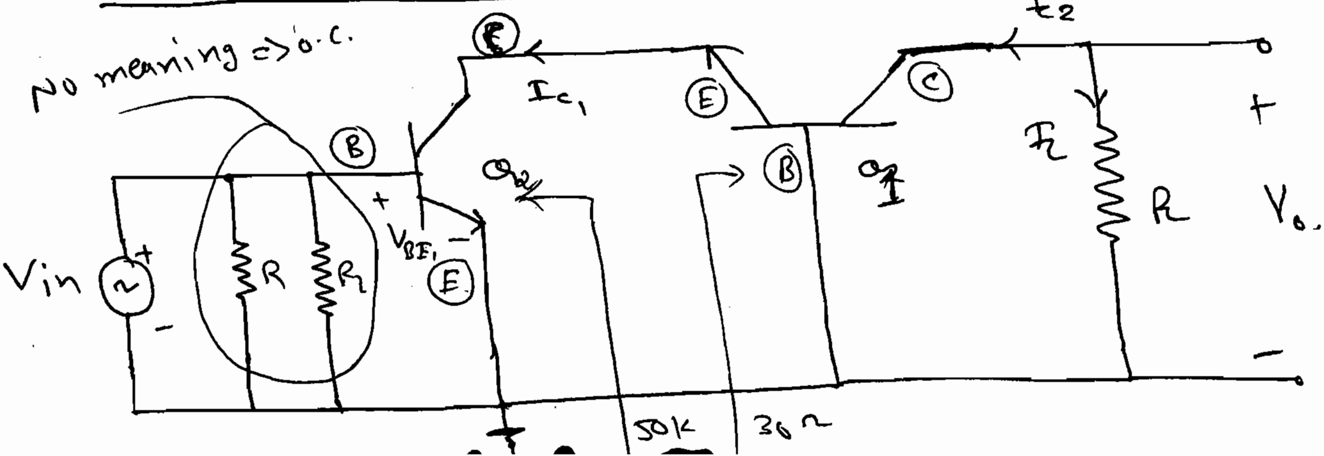
See Sujal's VLSI note.



→



→ for AC picture S.C. C



$$\rightarrow \quad g_m = \frac{I_{C(AC)}}{V_{BE(AC)}}.$$

$$I_E = -I_L.$$

$\therefore$ $V_{in} = V_{BE(AC)}$.

$\therefore$ $\cancel{V_o}$ $V_o = I_L R_C$

$$V_o = -I_C R_C = -I_{C(AC)} R_C$$

$$\therefore \quad A_V = \frac{V_o}{V_{in}} = \frac{-I_{C(AC)} \cdot R_C}{V_{BE(AC)}}.$$

$$\therefore \quad \boxed{A_V = -g_m \cdot R_C.}$$

$\rightarrow$ $BW = \frac{1}{RC}$, Time constant = RC.

$C_{eq} \uparrow$ (miller effect)

R $\downarrow$ (Cross) impedence mismatch.

→ one way to improve BW is by giving -ve feedback but -ve feedback reduced the gain.

→ But in ~~Bi~~ Casecode Amplifier BW is increased without Reducing gain.

→ Casecode: Connection of Ⓒ of CE to the Ⓑ of CB is called

→ Casecode: O/P of one stage is connected to the I/P of another stage.

* Advantages:

→ Wider BW.

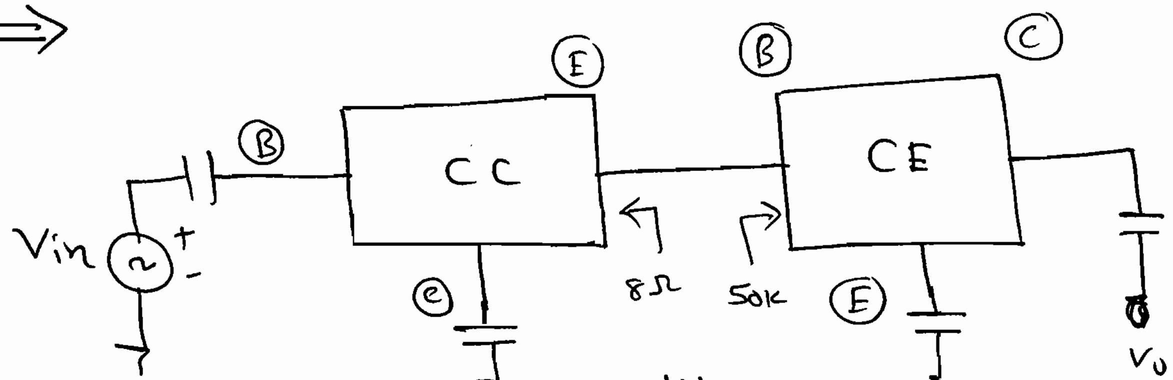
→ The overall transconduction of casecode Amp = the larger transconduction of Common Emitter amplifier.

→ Large output Impedence.

* Common Collector With Common Emitter.

[wideBand Structure].

⇒



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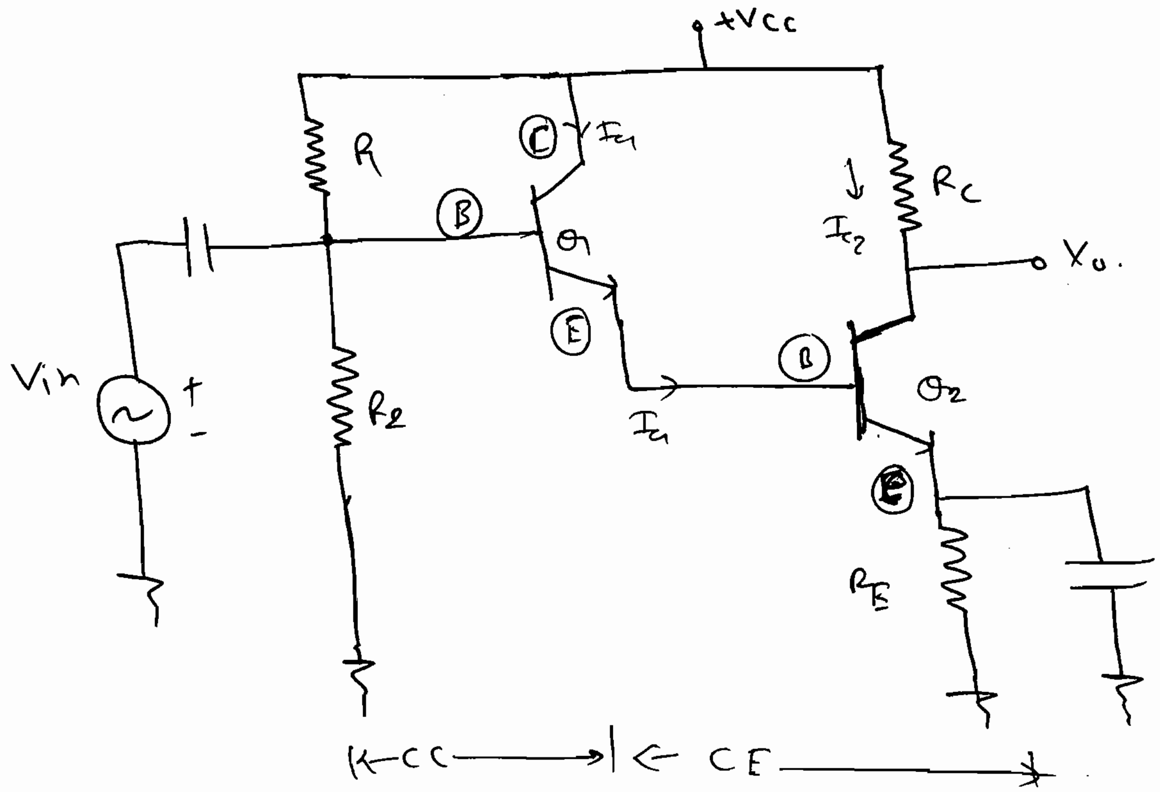
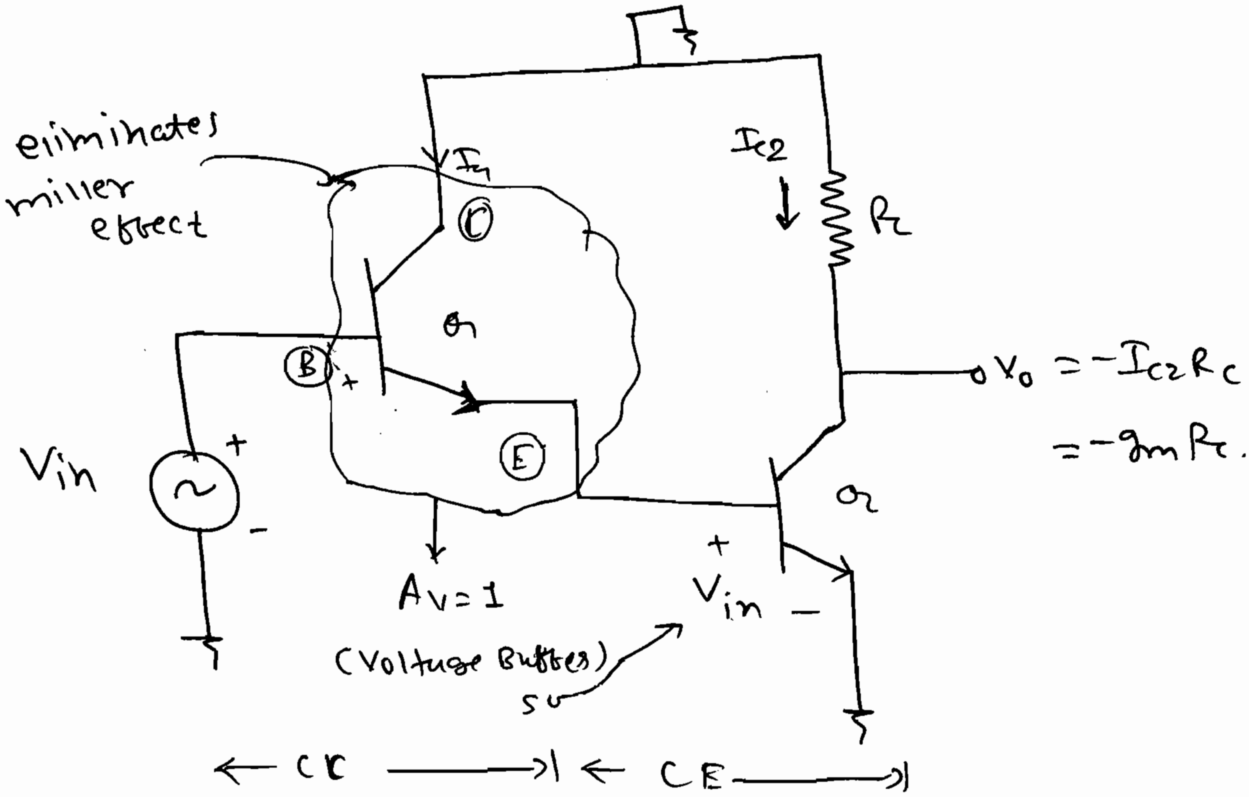


→ Ac picture:



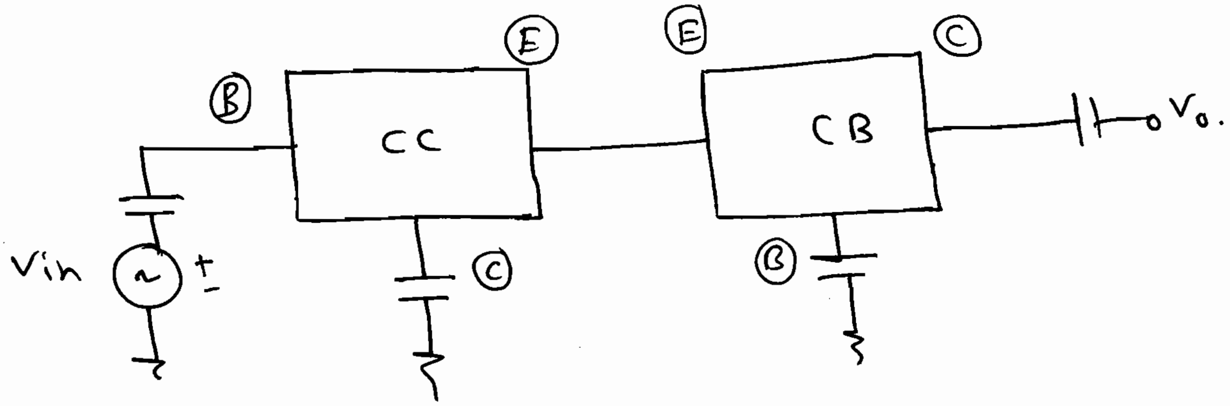
→ Current Buffer at o/p (A_I = 1) (or) Voltage Buffer at i/p (A_v = 1) is put inorder to avoide miller's effect.

→ The overall transconductance is g_m and voltage gain,

$$\therefore \boxed{A_v = -g_m R_c}$$

* Common Collector with Common Base:

→



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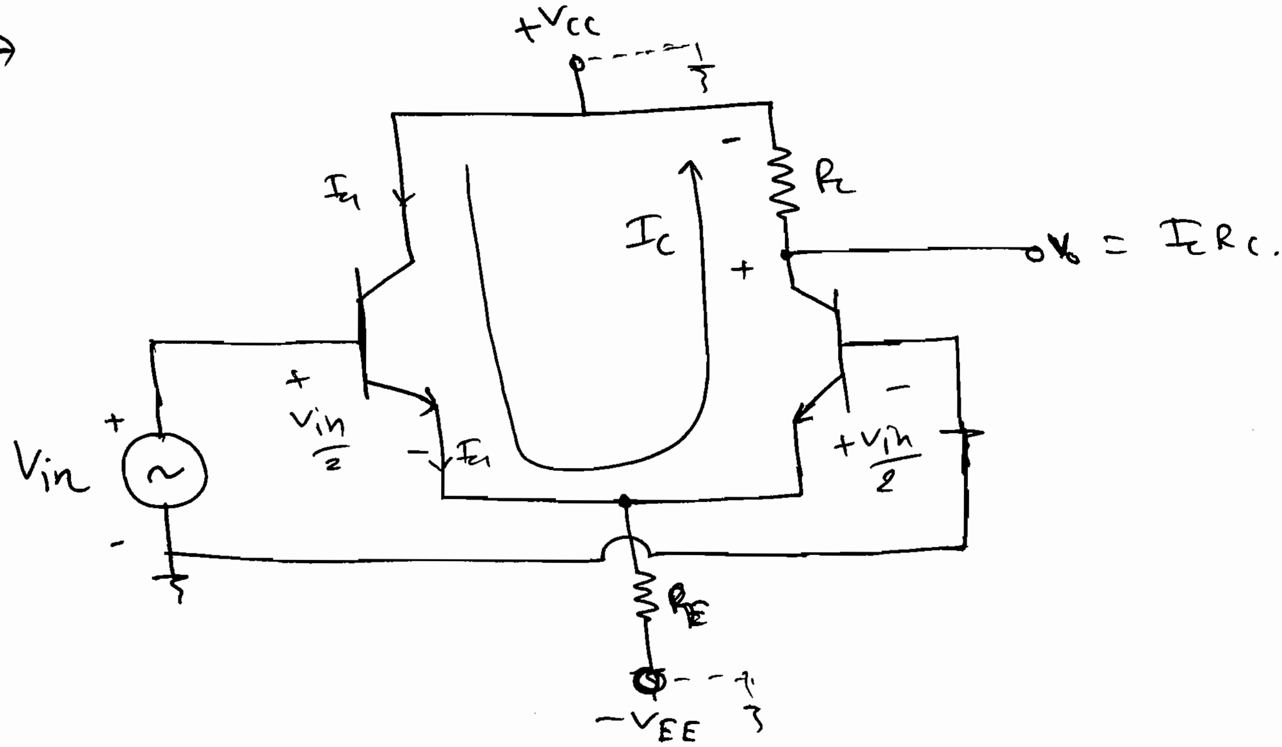

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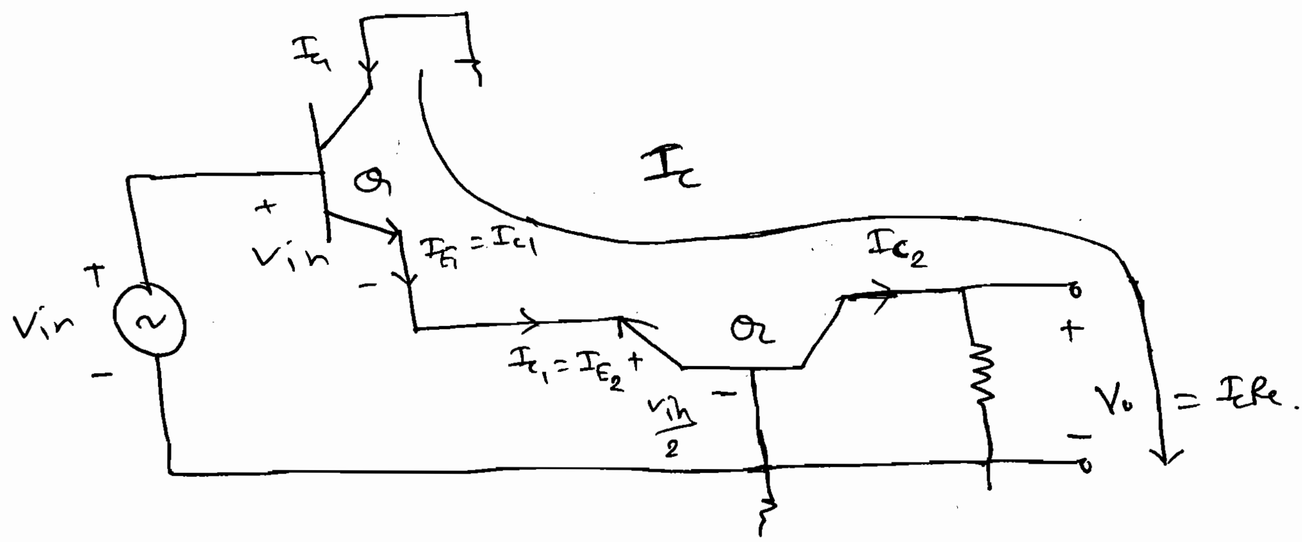


→ $V_o = I_c R_c$

$$\therefore \quad g_m = \frac{I_{C(AC)}}{V_{BE(AC)}} \quad , \quad V_{BE} = \frac{V_{in}}{2}.$$

$$\therefore \quad g_m = \frac{I_{C(AC)}}{V_{in}/2}$$

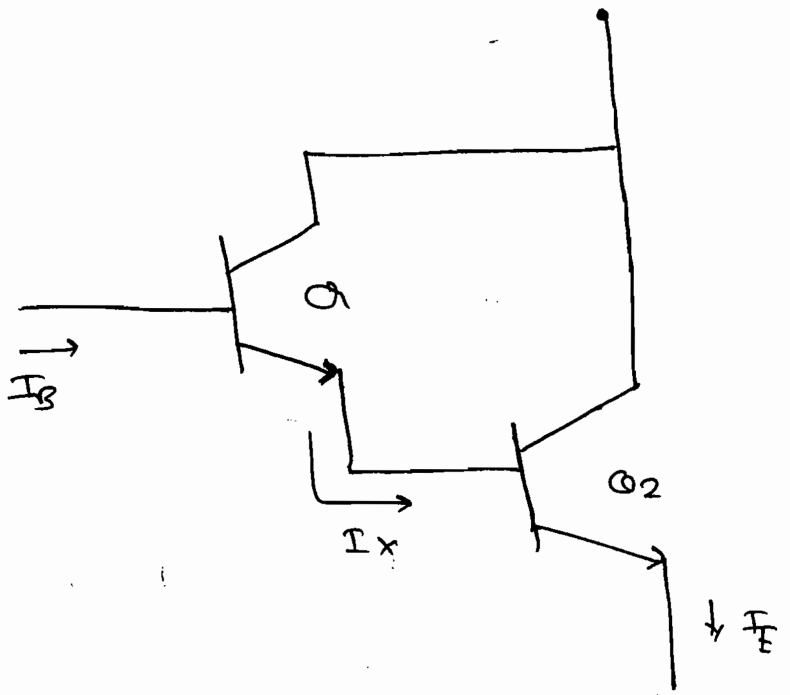
$$\therefore \quad \frac{g_m}{2} = \frac{I_{C(AC)}}{V_{in}},$$

$$\therefore \quad A_V = \frac{V_o}{V_{in}} = \frac{I_C \cdot R_C}{V_{in}}.$$

$$\therefore \quad \boxed{A_V = + \frac{g_m}{2} \cdot R_C.}$$

☆ Darligton Transistor Pair:

→ Advantges: :- High current gain, High i/p impedence.



→ $I_E = (\beta+1)\, I_x$.

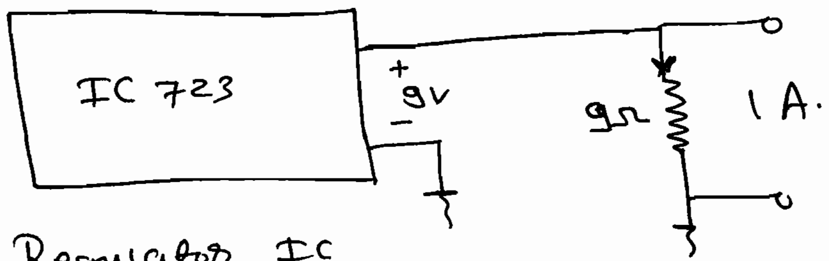
But $I_x = (\beta+1)\, I_B$.

So, $\boxed{I_E = (\beta+1)^2\, I_B}$.

→ To deal with worst load, darligton pair used.

let, $9\,\Omega$ load

⇒



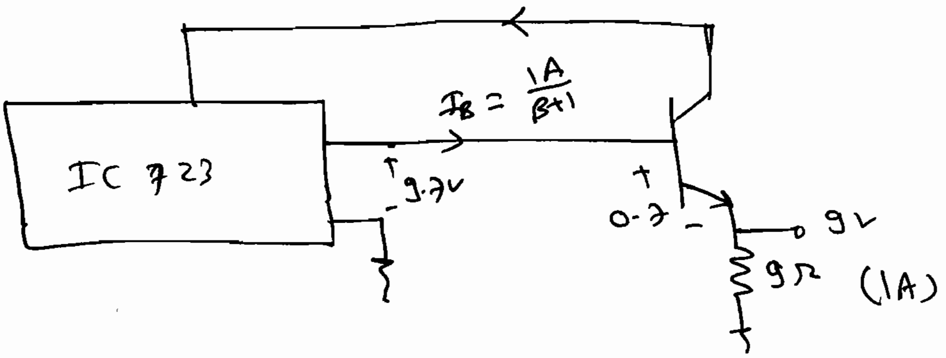
Regulator IC

→ Here, Voltage at Ic o/p is, 9v and load is connected which is $9\,\Omega$. So, current flowing through the ckt is 1A which is too high for the IC723. because IC723 can handle maximum current upto 100mA. and Ic gets burn.

→ Now, Put transistor as shown in figure.

let

$\boxed{\beta = 10}$

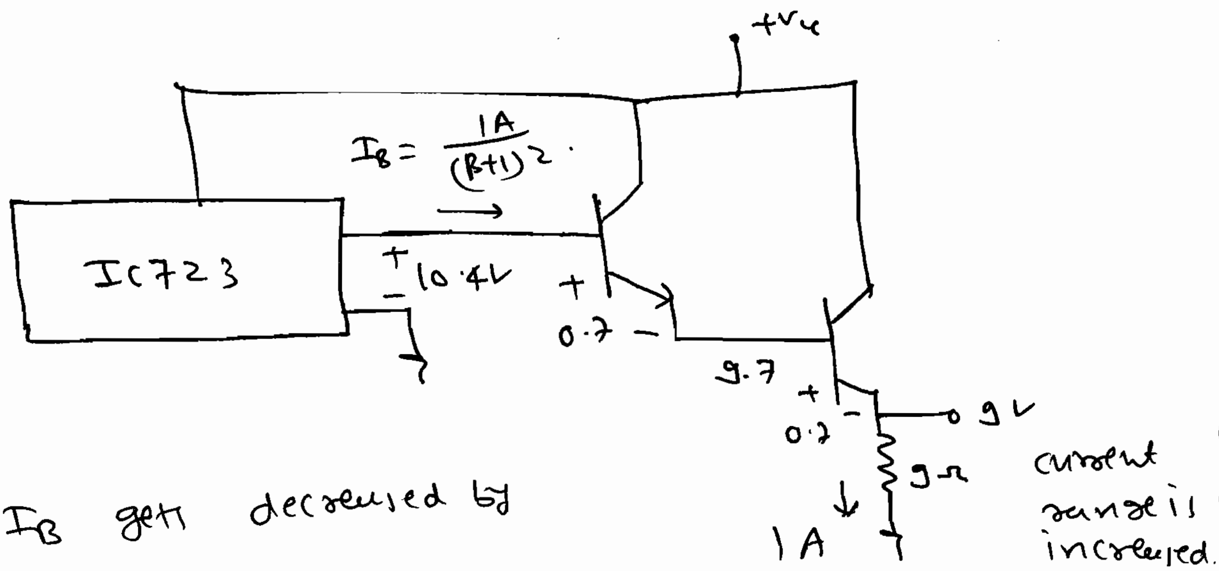


$I_B = \frac{1}{10}x$

$\boxed{I_B = 100\,mA}$

which is also high

Now, use Darlington pair of Transistor.



→ I_B gets decreased by $(\beta+1)^2$

$\therefore I_B = \frac{1}{100}$

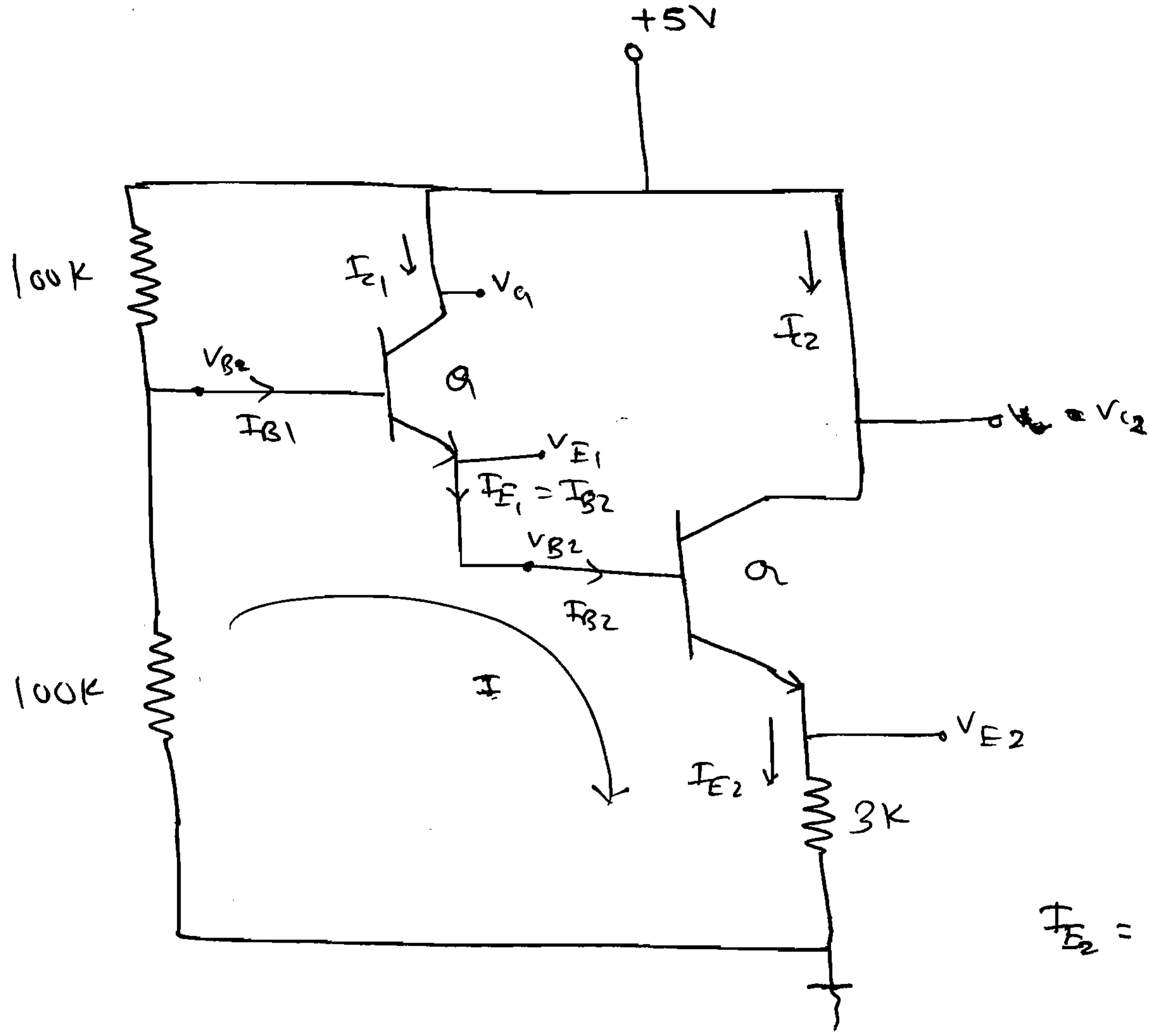
$\therefore \boxed{I_B = 10mA.}$

→ Now, IC can driven by darlington pair of transistor.

→ Now, Inorder to produce 9V across the 9Ω load 1 A current is available because of darlington pair even if current flowing through IC is 10mA. The required current gain (10mA to 1A) is provided by darlington pair.

Ex-1 Calculate node Voltage and Branch current. 9

take $\beta = 75$.



$$I_{E_2} = \frac{I_{B2}}{\beta+1}$$

→ $V_{th} = \frac{100}{200} \times 5 = 2.5V.$, $R_{th} = 50K$

$\therefore$ $V_{th} - I_{B1} R_{th} - V_{BE} - V_{BE} - I_{E2} R_{E2} = 0.$

$\therefore$ Now, $I_{E2} = \frac{I_{B2}}{(\beta+1)}.$

But $I_{B2} = \frac{I_{B1}}{(\beta+1)}.$

So, $I_{E2} = \frac{I_{B2}}{(\beta+1)^2}.$

$$\therefore \quad I_{E2} = \frac{V_{th} - 2V_{BE}}{R_E + \frac{R_{th}}{(\beta+1)^2}}.$$

$$\therefore I_{E_2} = \frac{2.5 - 1.4}{3000 + \frac{50000}{(76)^2}}$$

$$\therefore \boxed{I_{E2} = 0.366\,mA}$$

$$\therefore I_{C2} = \frac{\beta}{\beta+1} \times I_{E2}$$

$$\therefore I_{C2} = \frac{75}{76} \times 0.366$$

$$\boxed{I_{C2} = 0.361\,mA}$$

$$\therefore I_{B2} = I_{E2} - I_{C2}$$

$$\therefore \boxed{I_{B2} = 4.815\,\mu A}$$

$$\therefore \boxed{I_{E1} = 4.815\,\mu A}$$

$$\therefore I_{C1} = \frac{75}{76} \times 4.815$$

$$\therefore \boxed{I_{C1} = 4.75\,\mu A.}$$

$$\therefore \boxed{I_{B1} = 63.35\,nA.}$$

$$\therefore V_{B1} = V_{th} - I_{B1} \cdot R_{th}$$

$$\therefore V_{B1} = 2.5 - (63.35 \times 10^{-9} \times 50 \times 10^{3}).$$

$$V_{B1} = 2.5 - 0.003167$$

$$\therefore \boxed{V_{B1} = 2.496\,V}$$

$$V_{E1} = V_{B1} - 0.7$$

$$\therefore \boxed{V_{E1} = 1.796\,V}$$

$$\boxed{V_{C1} = 5V}$$

$$\boxed{V_{C2} = 5V}$$

$\therefore \quad V_{E2} = I_{E2} \times R_E$

$\therefore V_{E2} = 0.36 \times (3).$

$\therefore \boxed{V_{E2} = 1.098V}.$

$\therefore \quad V_{CE1} = V_{C1} - V_{E1}$

$= 5 - 1.796$

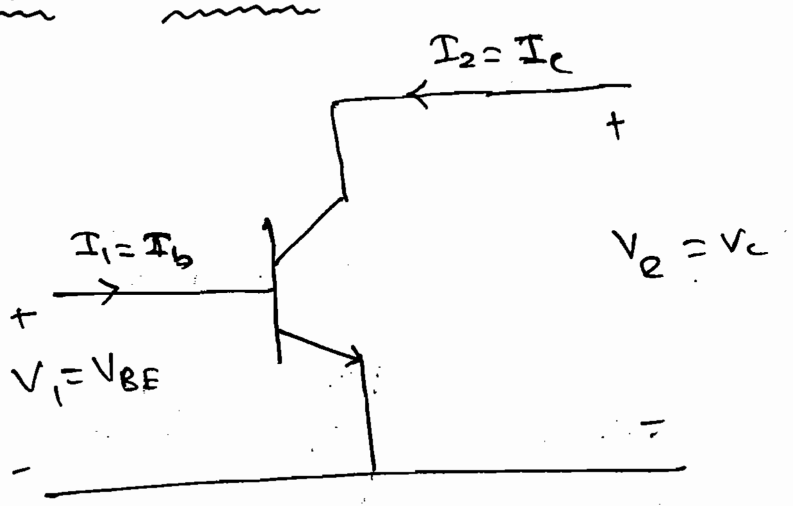
$\therefore \boxed{V_{CE1} = 3.204}$

$\therefore \quad V_{CE2} = V_{CE1} + 0.7$

$\therefore V_{CE2} = 3.204 + 0.7$

$\therefore \boxed{V_{CE2} = 3.914V}$

Hybrid Model:

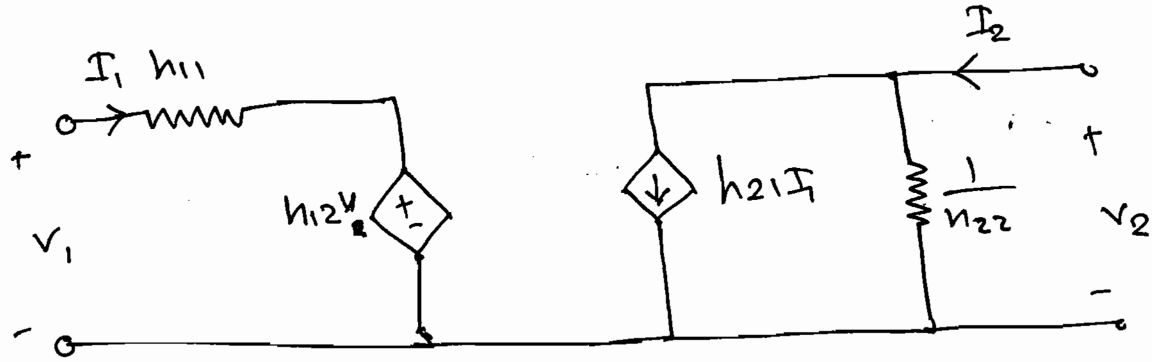


$\rightarrow$ $V_1 = h_{11} I_1 + h_{12} V_2$ (KVL, thevenian)

$I_2 = h_{21} I_1 + h_{22} V_2$. (KCL, Norton).

let, $V_1 = V_{BE}$, $V_2 = V_{CE}$ $\quad$ $h_{11} = h_{ie}$, $h_{12} = h_{re}$

$I_1 = I_B$, $I_2 = I_C$. $\quad$ $h_{21} = h_{fe}$, $h_{22} = h_{oe}$



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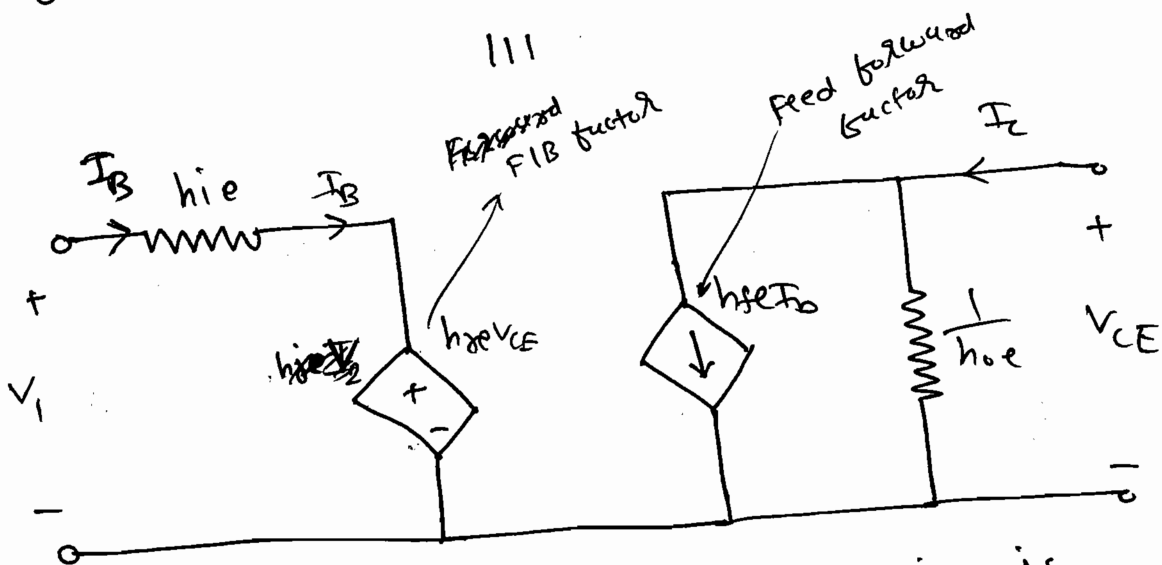


Where, $h_{11} = h_{ie}$ $\quad$ $h_{12} = h_{re}$

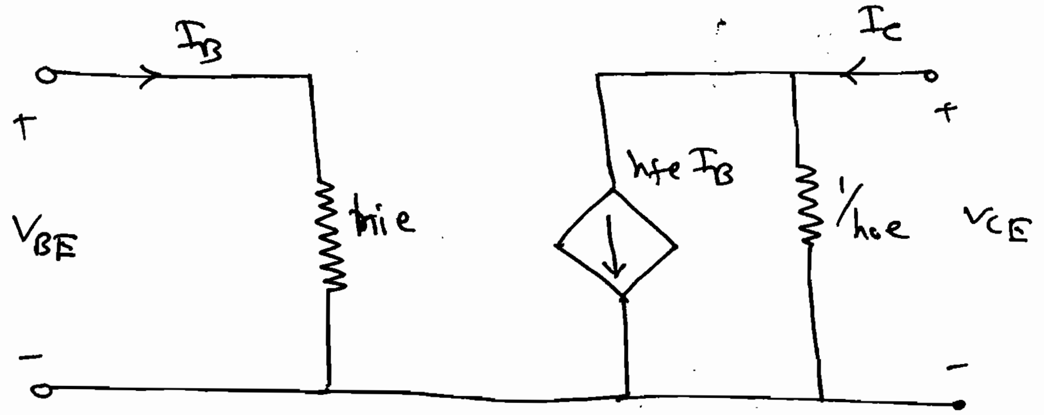
$h_{21} = h_{fe}$ $\quad$ $h_{22} = h_{oe}$.

This is H model of Transistor.

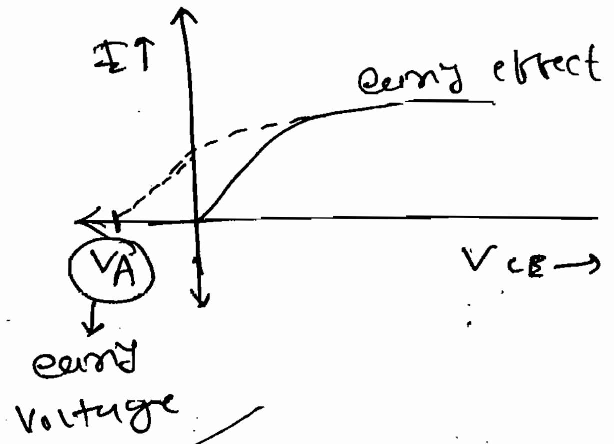
2:

→ as the $h_{re} = 10^{-12}$ and $h_{fe} = 100$.

we can negate h_{re} and the ckt will be.



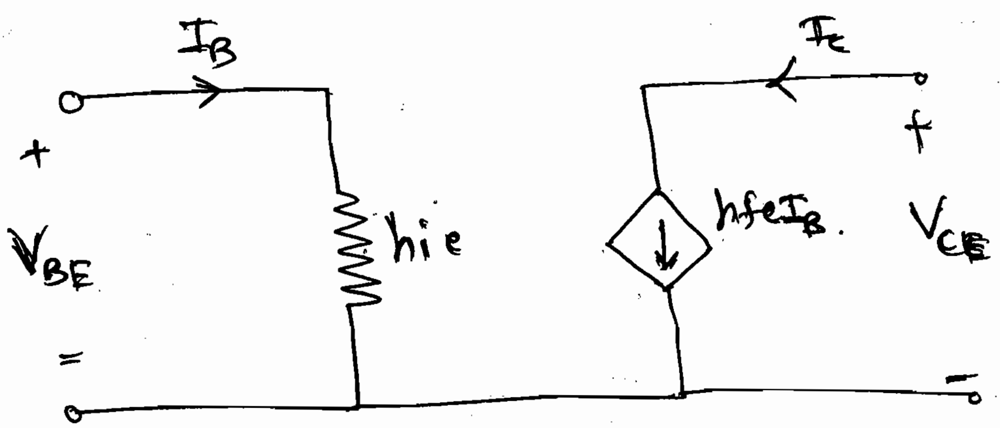
Now, $h_{oe} = \frac{I_C}{V_{CE}}$.



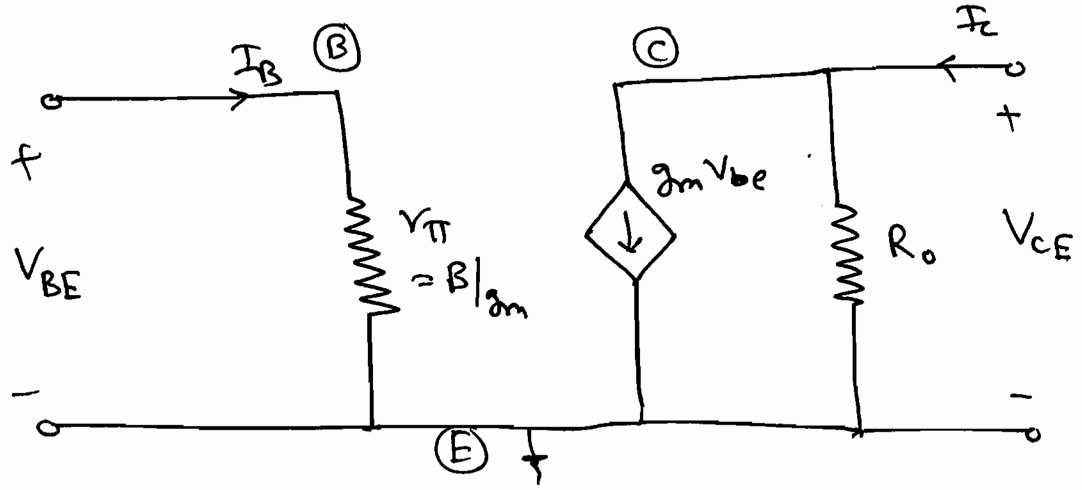
$\frac{1}{R_o} = \frac{I_C}{V_{CE}} = \frac{1}{\text{slope}}$

$\boxed{h_{oe} = 0.}$

So final H-model is as below:



* π Model is seeing from base.



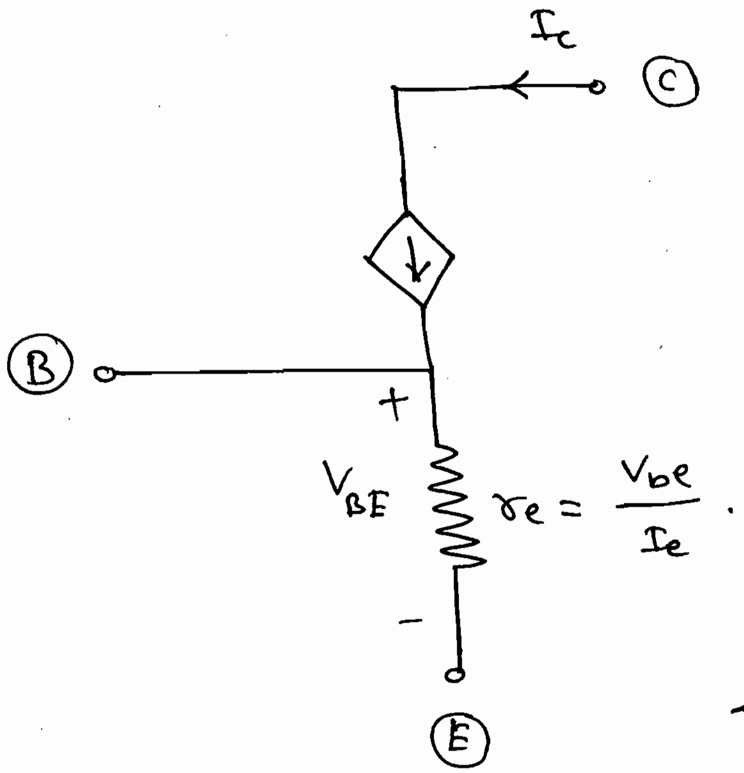
⇒ 1) $r_\pi = h_{ie} = \beta / g_m$.

2) $h_{fe} = \beta$

$\boxed{g_m = \frac{h_{fe}}{h_{ie}}}$.

3) $R_o = \frac{1}{h_{oe}} = \frac{V_A}{I_{C_{DC}}}$.

* T- Model:



gain

$\frac{V_o}{V_{in}} = -g_m R_c$.

$\therefore \boxed{A = -\frac{h_{fe}}{h_{ie}} \cdot R_c}$.

← T model is seeing through emitter.

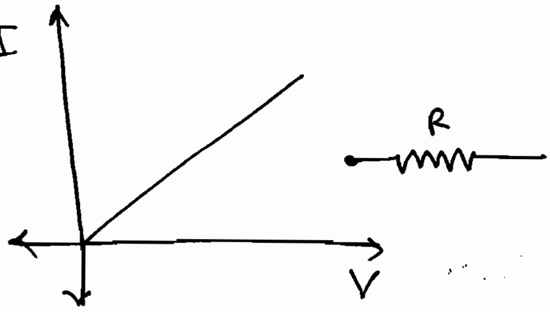
⇓

to find operting point.

$\therefore r_e = \frac{V_{be}}{I_e} = \frac{V_{be}}{I_c}$.

$\therefore \boxed{r_e = 1/g_m}$

*



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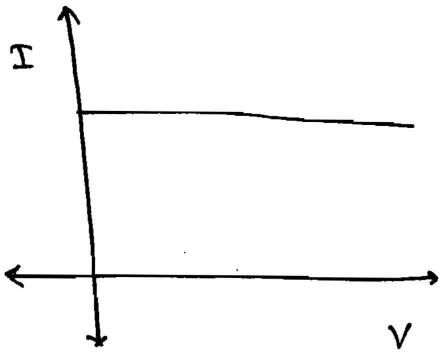
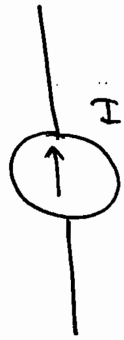
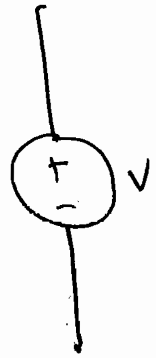




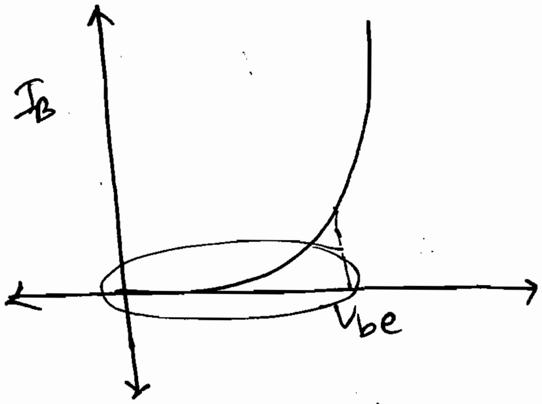
current source.

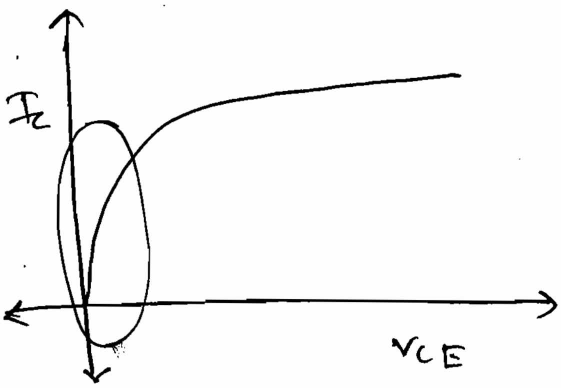
*



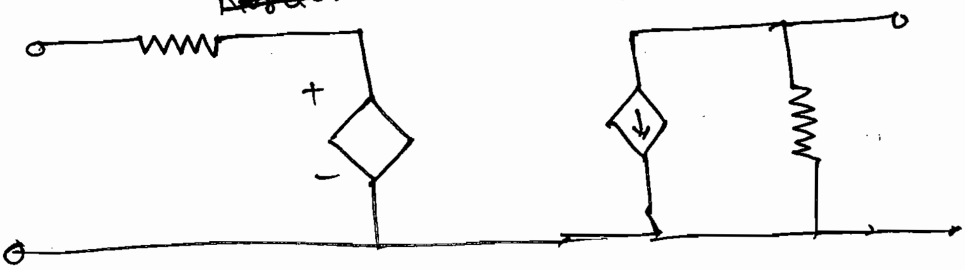
Voltage Source.

*



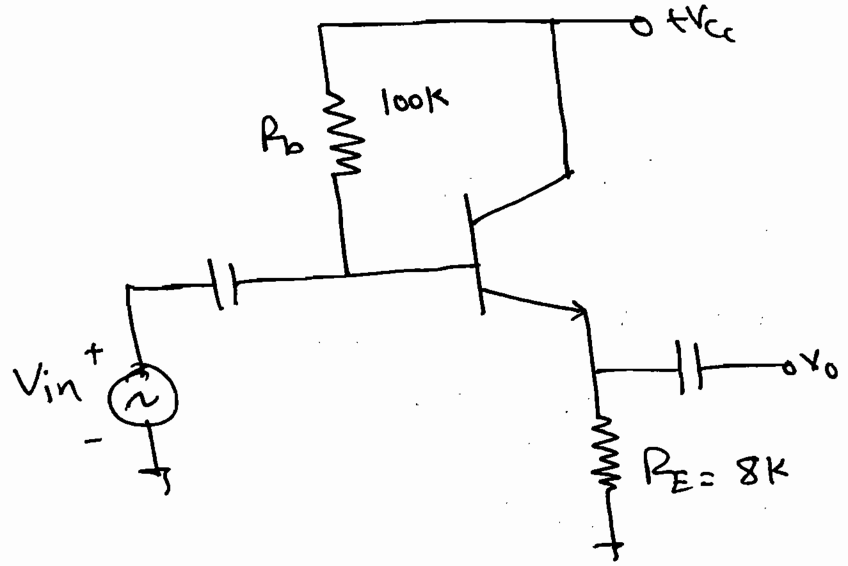


Thevinin ~~Norton~~ + Norton.

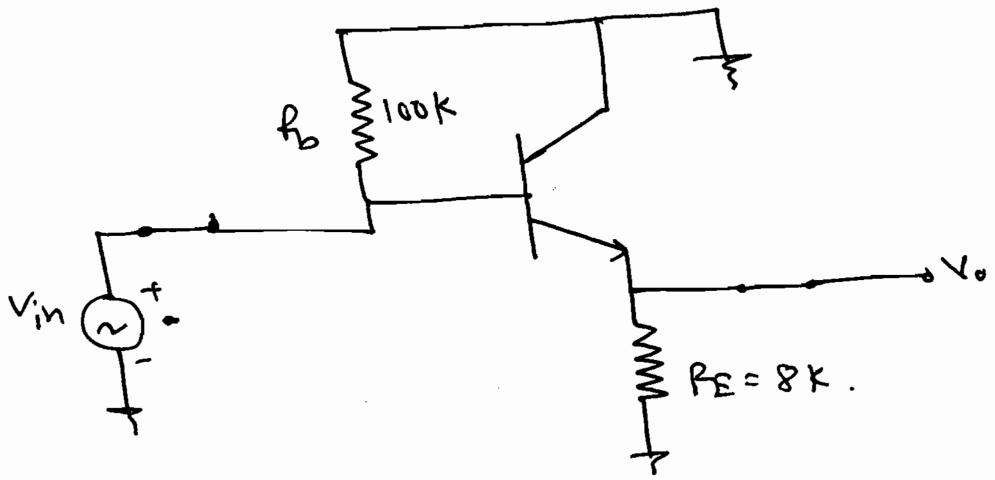


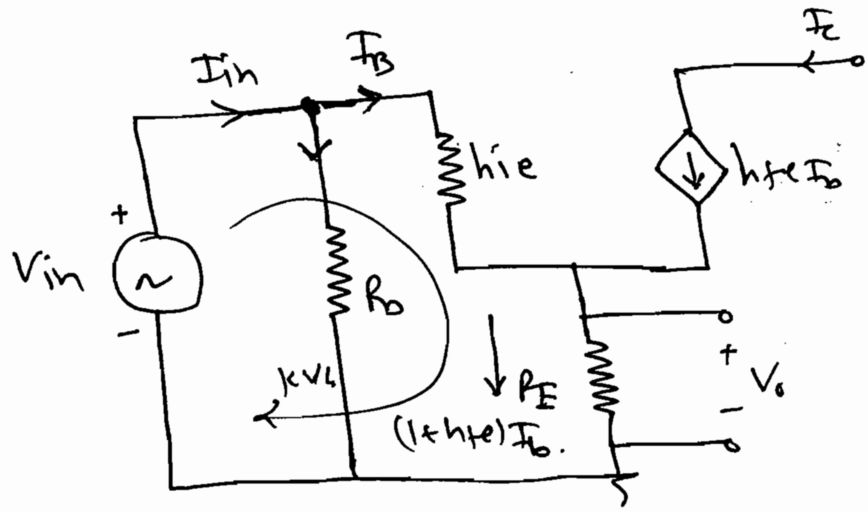
Ex-1 For emitter follower circuit given calculate input impedence, o/p impedence and voltage gain. $h_{ie} = 1K$, $h_{fe} = 100$.

Ans:



→ Ac picture:





$$V_o = (1+h_{fe})\, I_B \cdot R_E.$$

$$\therefore\ V_{in} - I_b h_{ie} - (1+h_{fe}) I_b R_E = 0.$$

$$\therefore\ V_{in} = I_b [\, h_{ie} + R_E (1+h_{fe})].$$

$$\therefore\ \text{Voltage gain} = A_v = \frac{V_o}{V_{in}}.$$

$$\therefore\ A_v = \frac{R_E (1+h_{fe})}{h_{ie} + R_E (1+h_{fe})}.$$

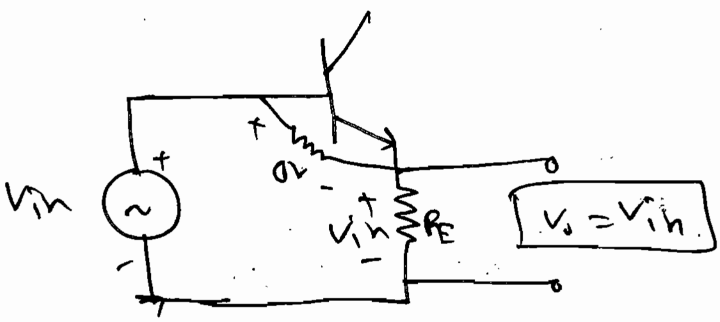
$$\therefore\ A_v = \frac{8000\,(1+100)}{1000 + 8000\,(1+100)}.$$

$$\therefore\ \boxed{A_v = 0.99876.}$$

We can negate h_{ie} at the begining and

$$\therefore\ A_v = \frac{R_E (1+h_{fe})}{R_E (1+h_{fe})}$$

$\boxed{A_v \approx 1}$ so, emitter follower



$$\therefore\ Z_{in} = \frac{V_{in}}{I_{in}}.$$

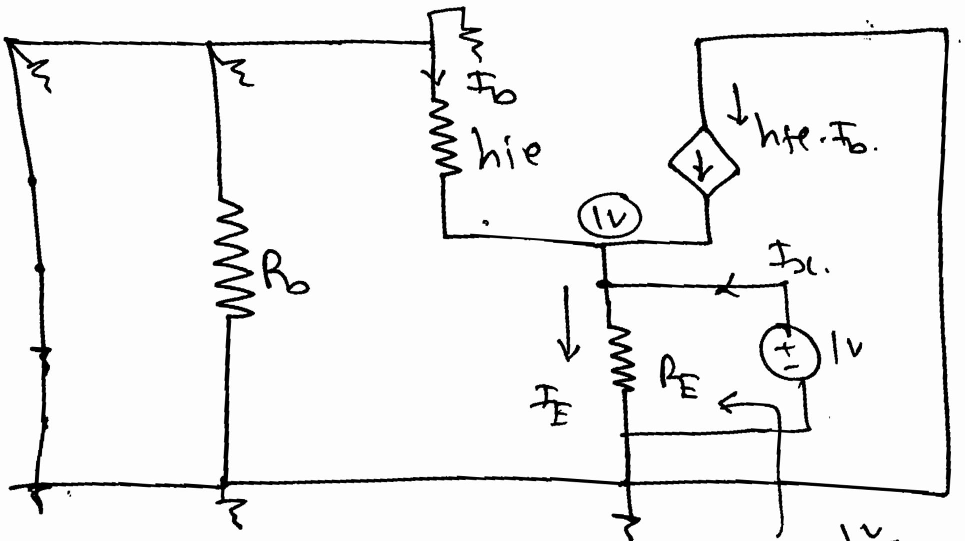
$$\therefore\ I_{in} = I_b + \frac{V_{in}}{R_b}.$$

$$\therefore \quad I_{in} = \frac{V_{in}}{R_b} + \frac{V_{in}}{h_{ie} + (1+h_{fe})R_E}.$$

$$\therefore \quad \frac{V_{in}}{I_{in}} = \frac{1}{\frac{1}{R_b} + \frac{1}{[h_{ie} + (1+h_{fe})R_E)]}}$$

$$\therefore \quad \boxed{Z_{in} = R_b \,||\, [\,h_{ie} + (1+h_{fe})R_E)].}$$

→ Now, finding o/p impedence.



KCL

$$\therefore \quad I_b + I_x + I_c = I_E.$$

$$\therefore \quad \frac{0-1V}{h_{ie}} + I_x + h_{fe}.\left(\frac{0-1}{h_{ie}}\right) = \cancel{(1+h_{fe})I_b}\,.\,\frac{1V}{R_E}.$$

$$\therefore \quad (1+h_{fe})\left(-\frac{1}{h_{ie}}\right) + I_x = \frac{1}{R_E}.$$

$$\therefore \quad I_x = \frac{1}{R_E} + \frac{1+h_{fe}}{h_{ie}}.$$

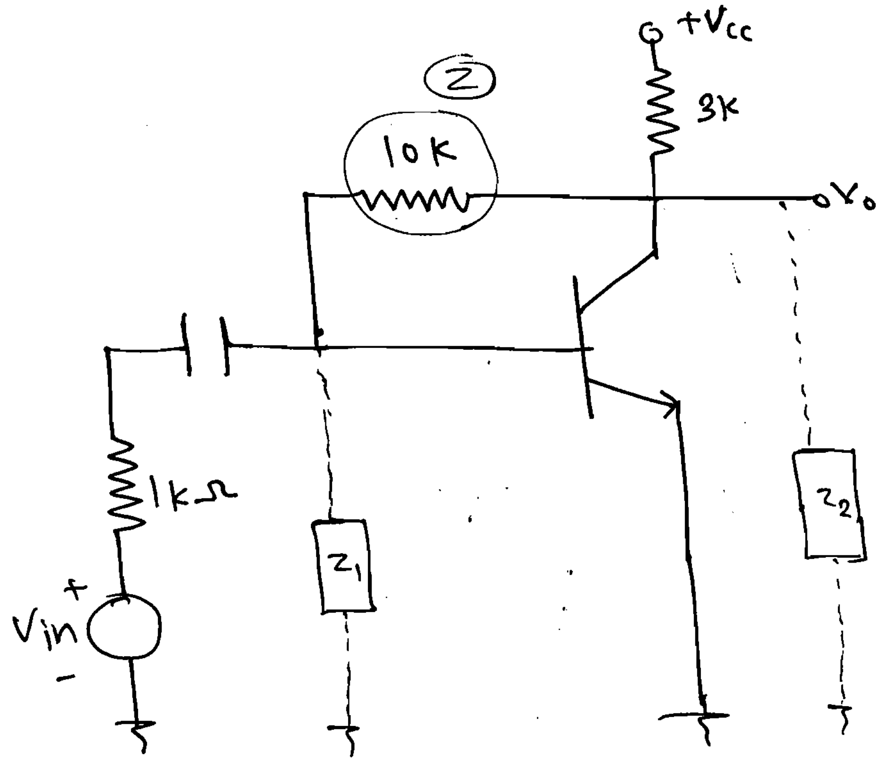
$$\therefore \quad Z_o = \frac{1.V}{I_x}.$$

$$\therefore \quad Z_o = \frac{1}{\frac{1}{R_E} + \frac{1}{h_{ie}}}$$

$\therefore \boxed{Z_o = R_E \parallel \frac{h_{ie}}{1+h_{fe}}}$

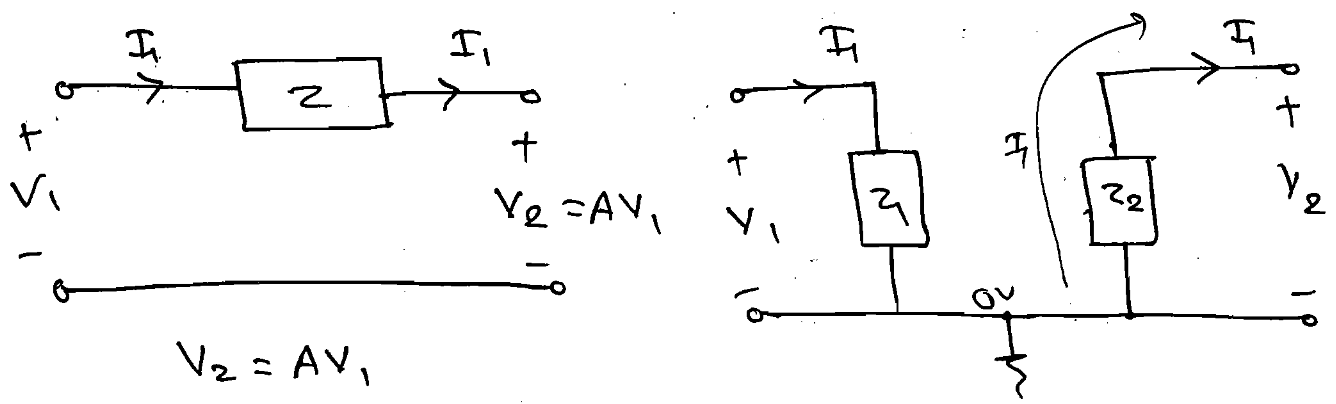
GATE, IES

Ex-2 Using the millers theorem find the voltage gain V_o/V_{in} if $h_{ie} = 1K$, $h_{fe} = 100$.



Ans:

* Miller's theorem:



$V_2 = AV_1$

$\rightarrow I_1 = \frac{V_1 - V_2}{Z}$,

$I_1 = \frac{V_1 - 0}{Z_1}$.

$\therefore \frac{V_1 - V_2}{Z} = \frac{V_1 - 0}{Z_1}$. but $V_2 = AV_1$

$$\therefore \frac{V_1 - AV_1}{Z} = \frac{V_1}{Z_1}.$$

$$\therefore \frac{\cancel{V_1}(1-A)}{Z} = \frac{\cancel{V_1}}{Z_1}.$$

$$\therefore \boxed{Z_1 = \frac{Z}{1-A}.}$$

similarly, $$I_1 = \frac{V_1 - V_2}{Z} = \frac{0 - V_2}{Z_2}.$$

$\therefore$ But $V_2 = AV_1$

$\Rightarrow V_1 = V_2/A.$

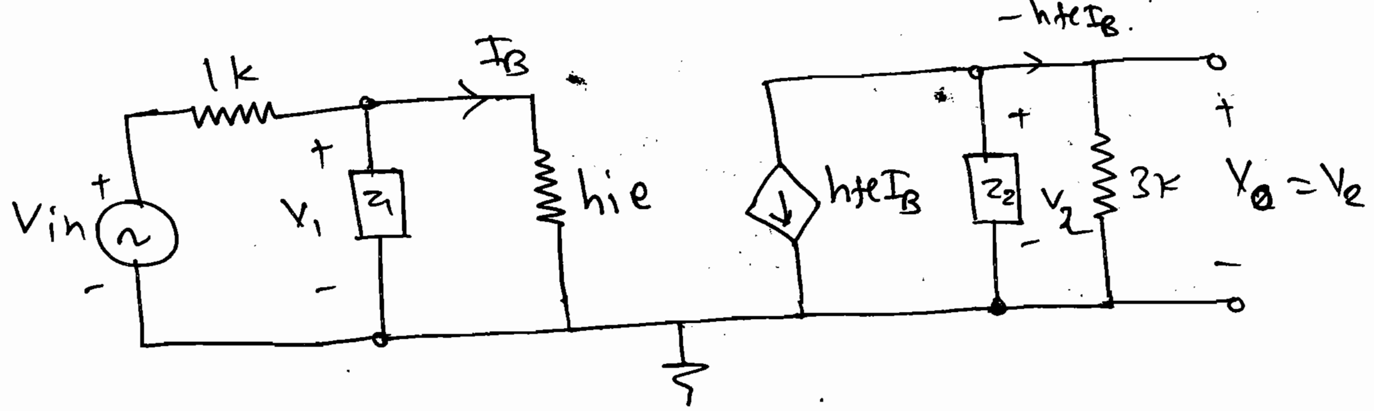
$$\therefore \frac{\frac{V_2}{A} - V_2}{Z} = \frac{-V_2}{Z_2}.$$

$$\therefore \frac{\cancel{V_2}\left(\frac{1}{A} - 1\right)}{Z} = \frac{-\cancel{V_2}}{Z_2}$$

$$\therefore Z_2 = \frac{Z}{1 - 1/A}.$$

$$\therefore \boxed{Z_2 = \frac{ZA}{A-1}.}$$

Now, Ac picture,



$$Z_1 = \frac{10K}{1-A}.$$

$$A = \frac{V_2}{V_1} = \frac{V_o}{V_1}$$

$$Z_2 = \frac{10K\,A}{A-1}.$$

$$\boxed{A = V_o/V_1}$$

$\therefore \quad V_o = -h_{fe} I_B \cdot [3K \| Z_2].$

$\therefore \quad V_1 = I_B h_{ie}.$

$V_1 = I_B (1K).$

$\therefore \quad A = \frac{V_o}{V_1} = \frac{-h_{fe}[3K \| Z_2]}{h_{ie}}.$

$\therefore \quad A = -\frac{100}{1000}\left[\frac{1}{\frac{1}{3000} + \frac{10KA}{A-1}}\right].$

$\therefore \quad +10A = \frac{-1}{\frac{1}{3000} + \frac{10000A}{A-1}}.$

$\therefore \quad 10A\left[\frac{1}{3000} + \frac{1}{\frac{10000A}{A-1}}\right] = -1.$

$\therefore \quad 10A\left[\frac{1}{3000} + \frac{A-1}{10000A}\right] = -1.$

$\therefore \quad \frac{10A}{3} + \frac{(A-1)}{1} = -1000.$

$\therefore \quad 10A + 3(A-1) = -3000$

$\therefore$

$\therefore$

$\therefore \quad 13A - 3 = -3000$

$13A = -2997$

$\therefore \quad \boxed{A = -230.54}$

$$\therefore z_1 = \frac{10000}{1-A} \qquad z_2 =$$

$$\therefore z_1 = \frac{10000}{232}$$

$$\boxed{z_1 = 43.10\,\Omega}$$

$$z_2 = \frac{10k \times A}{A-1} = 10k.$$

$$\therefore \boxed{z_2 = 10k}$$

KCL

$$\therefore \frac{V_{in} - V_1}{1k} = \frac{V_1}{z_1} + \frac{V_1}{1k}.$$

$$\therefore V_1 \left[\frac{1}{1000} + \frac{1}{43.2} + \frac{1}{1000} \right] = \frac{V_{in}}{1000}.$$

$$\therefore V_1 [2 + 23.20] = V_{in}.$$

$$\therefore \frac{V_1}{V_{in}} = \frac{1}{25.20}$$

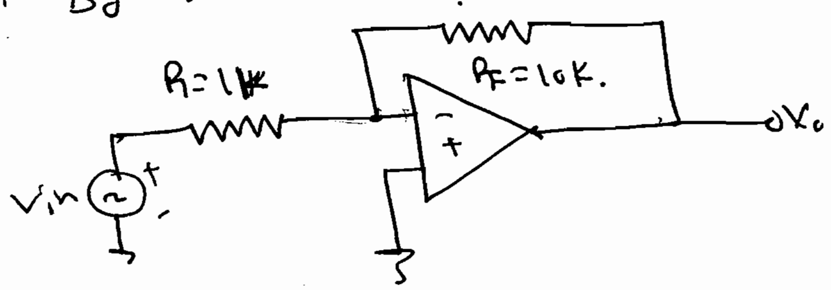
$$\therefore \frac{V_o}{V_{in}} = \frac{V_o}{V_1} \cdot \frac{V_1}{V_{in}}$$

$$= (-232) \times \left(\frac{1}{25.20}\right)$$

$$\therefore A = \frac{V_o}{V_{in}}$$

$$\therefore \boxed{A = -9.2}$$

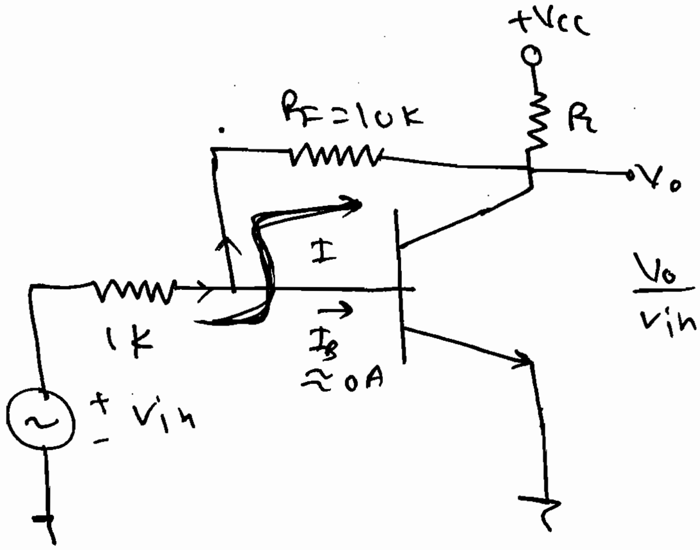
Now, By inspection we can do it easily.



$$\therefore V_o = -\frac{R_f}{R_1} V_{in}$$

$$\therefore \frac{V_o}{V_{in}} = A_v \simeq -10.$$

*



$$\frac{V_o}{V_{in}} \approx -10 = A_v.$$